Impact to Underground Sources of Drinking Water and Domestic Wells from Production Well Stimulation and Completion Practices in the Pavillion, WY Field

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A - Regional and Local Geology

A.1 Structural Geology

The Pavillion Field is located in the west-central portion of the Wind River Basin (WRB) (Figure SI A1). The WRB is one of many structural and sedimentary basins that formed in the Rocky Mountain foreland (an elongate north-south structural depression flooded by a broad epicontinental sea referred to as the Western Interior Seaway) during the Laramide orogeny[1,2] (Late Cretaceous through early Eocene). The WRB is fault-bounded by Laramide uplifts with Washakie Range, Owl Creek Mountains, and southern Bighorn Mountains to the north, the Wind River Range to the west, the Granite Mountains to the south, and Casper arch to the east[1-4] (Figure SI A1).

Igneous and metamorphic rocks of Precambrian age comprise the core of the mountain ranges and underlie sedimentary rocks within the basin. Rocks from all geologic periods except Silurian age are present in the basin[5,6]. Sedimentary strata dip 10°- 20° along the south and west margins of the WRB and are commonly vertical to overturned in the north and east margins of the WRB resulting in marked asymmetry with the deepest portion of the of the basin on the north and eastern margins[3]. The center part of the basin is filled with nearly horizontal fluvial and lacustrine Quaternary and Cenozoic Tertiary age sediment, overlying Paleozoic and Mesozoic age rocks. Surface deposits in the basin interior, where the Pavillion field lies, consists of Quaternary alluvium and coalluvum and lower Eocene rocks of the Wind River Formation[3] in which over 1520 m of basin-fill strata was removed by post-lower Eocene erosion[4]. In the Pavillion area, the thicknesses of colluvial-alluvial deposits can be 6 m or more[7].

Oil and gas wells in the WRB are generally associated with anticlines or more subtle closures, however, controls on confinement cannot be discerned for some basin-centered gas accumulations[8]. The Pavillion Field is situated on a structural closure that lies on the hanging wall of Circle Ridge/Maverick Springs thrust fault – one of three major northwest-trending thrust fault systems transecting the WRB[3,9] (Figure SI A1). There is no publicly available information on the precise location of this fault in the Pavillion field. However, it appears to lie along the western portion of the field[10].

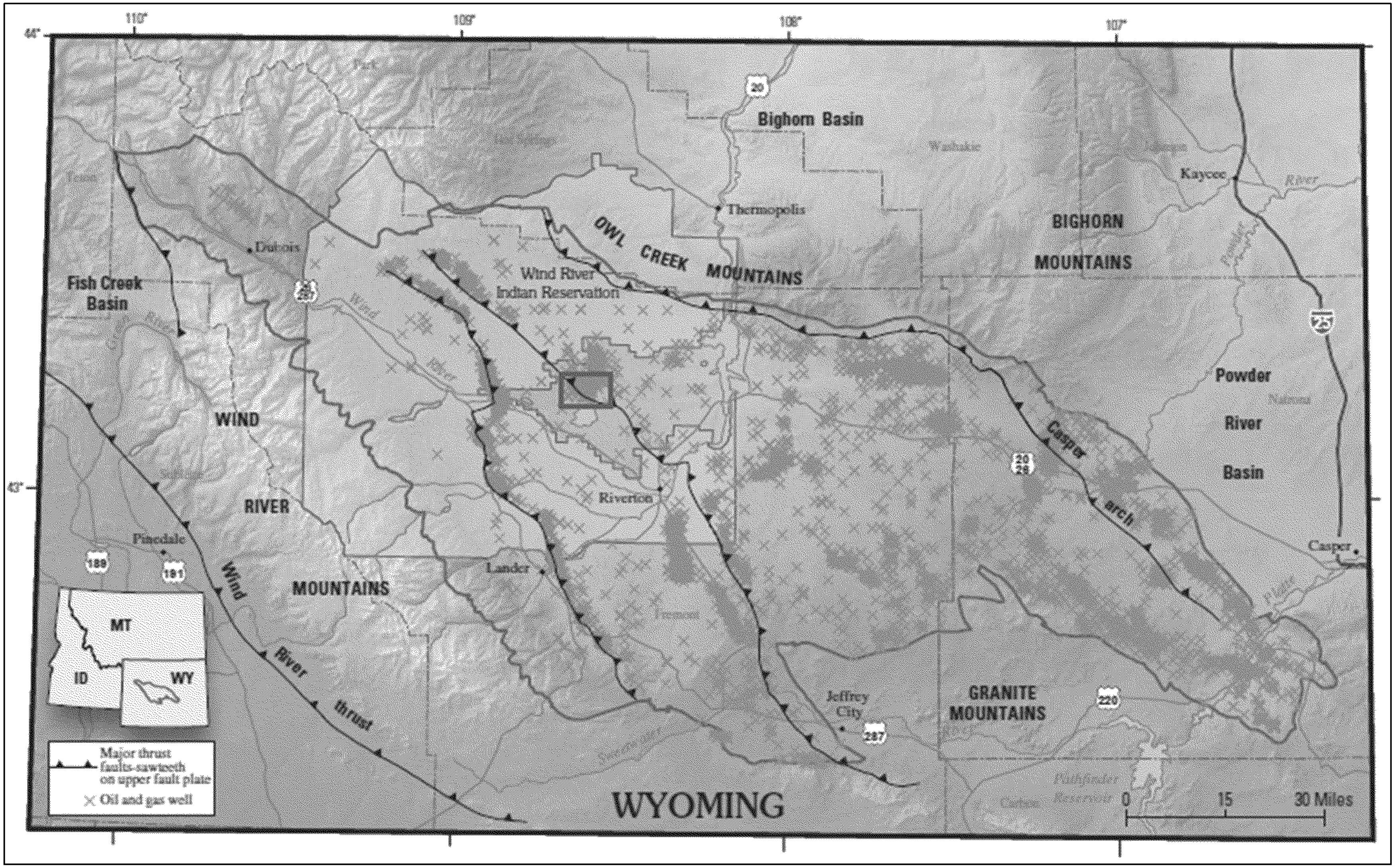

Figure SI A1. Boundaries of the Wind River Basin, identification of major faults, and the approximate location of the Pavillion Field (red square). Figure was modified from Nelson and Kibler[8].

A.2 Identification of Source Rocks and Hydrocarbon Migration

Hydrocarbon production from the Pavillion Field is primarily gas from the Paleocene Fort Union and overlying Early Eocene Wind River Formation. However, oil has also been produced from a number of production wells in these formations, especially in western portion of the field in proximity to the suspected location of a fault. Source rocks for gas generation consist of marine rocks deposited from Early to Late Cretaceous time (~105-80 Ma) including the Thermopolis Shale, Mowry Shale, Belle Fourche Member of the Frontier Formation, and Cody Shale and non-marine source rocks deposited from Late Cretaceous to Paleocene time (~82-55 Ma) including coal and carbonaceous shale from the Mesaverde, Meeteetse, and lower member of the Fort Union Formation[3] (Figure SI A2).

The source rock for oil production in the Pavillion Field is not explicitly identified in the literature. Oil was generated by source rocks in the Mowry Shale and lower shaly member of the Cody Shale throughout most of the deep basin but present day thermal maturities are too high for oil to be preserved in these source rocks except in marginal areas of the basin[3]. Oil generated by these source rocks may have migrated into shallow reservoirs but evidence is lacking[3]. The Waltman Shale Member of the Fort Union Formation is oil prone but absent at the Pavillion field[4,8] or at its western boundary[11].

Light hydrocarbons from the Fort Union and Wind River Formations are isotopically similar and "dry." For example, methane (C_1), $\delta^{13}C_1$ = -38.04 to -39.24‰ in Fort Union formation and $\delta^{13}C_1$ = -39.24 to -40.20‰ in Wind River Formation. The ratio of methane/methane to pentane (C_1/C_{1-5}) = 0.95 to 0.96 in Fort Union Formation and C_1/C_{1-5} = 0.95 and 0.96 in the Wind River Formation[12,13]. The high level of thermal maturity of light hydrocarbons is incompatible with gas generation from these formations indicating extensive upward vertical migration from underlying mature and post-mature Upper Cretaceous source rocks[13]. Thermal maturities of coal beds in Fort Union are low indicating that any gas present is either of biogenic origin or is migrated thermogenic gas[3].

In the Pavillion Field, light hydrocarbons are believed to have migrated and commingled in faulted and highly fractured zones along anticlines and structural noses[3,13-15]. Light hydrocarbons migrated to the base of the Waltman Shale Member[3] east of the Pavillion Field, and to Eocene Wind River Formation west of the pinchout of the Waltman Shale[12,13] where the Pavillion field is present. As uplift and erosion proceeded in the Wind River Basin, ground water produced an alteration zone where microbial activity generated biogenic methane from source rocks and degraded ethane in preexisting gas accumulations[3]. Biodegradation of ethane has occurred at the Pavillion and East Riverton dome fields[14].

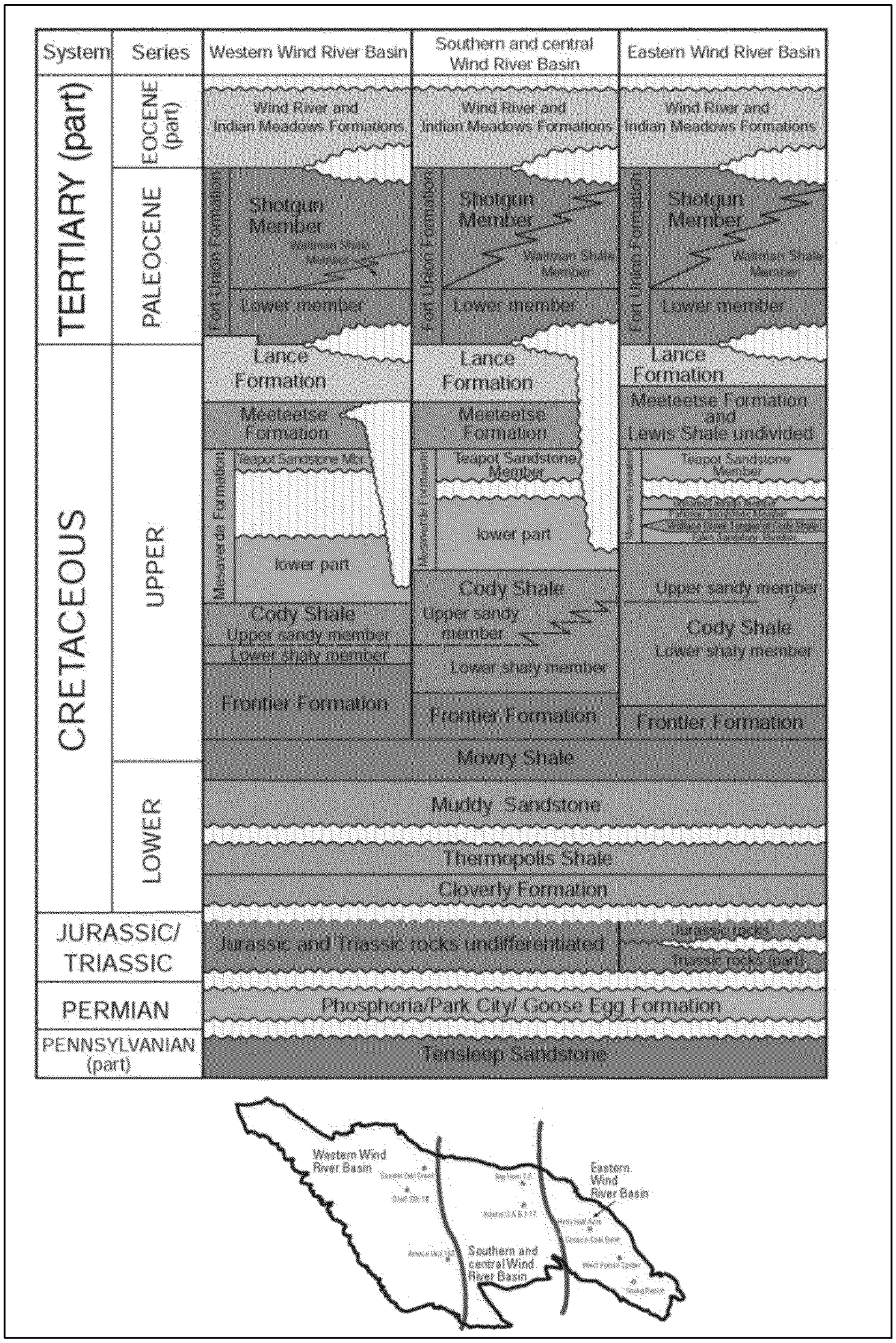

Figure SI A2. Generalized stratigraphic columns and correlations of Pennsylvanian through Eocene strata in the Wind River Basin, Wyoming. The Pavillion Field is located in the western portion of the Wind River Basin. From Johnson et al.[3]

Gas trapping in the Wind River and Fort Union Formations in the Pavillion field occurs in localized stratigraphic sandstone pinchouts on the crest and along flanks of a broad structural dome[9,10,16]. A decrease in fracturing away from the crest of a fold rather than loss of gas saturation largely may control economic gas production[3]. During early development of the Pavillion field, Upper Cretaceous and Tertiary rocks were normally pressured (hydrostatic gradient) and had a low temperature gradient of 1.2°F/100 ft[8]. Cumulative water to gas ratios, measured in barrels (bbls) (1 bbl = 42 gallons = 159 liters) to million cubic feet (MMCF), for targeted production intervals in the Wind River and Fort Union are considered relatively low at 0.9 bbl/MMCF (n=84) and 2.4 bbl/MMCF (n=66), respectively[8].

A.3 Lithology of the Fort Union Formation

The Fort Union Formation is divided into two general lithologic units. The lower unnamed member is characterized by conglomerates, white to gray fine- to coarse-grained, massive to cross-bedded standstone, interbedded with dark gray to black shale, claystone, and siltstone deposited under various fluvial depositional systems[3,17-19]. The upper unit is divided into two laterally equivalent members – the Waltman Shale and the Shotgun members[20]. The Waltman Shale is a lacustrine deposit in the central portion of the WRB that formed from an extensive body of water that developed in the basin during late Paleocene time[11]. The Waltman Shale is absent or at its western boundary at the Pavillion field[4,8,11].

The Shotgun Member is a marginal lacustrine deposit that formed in fluvial and shoreline areas that expanded during the late Paleocene[20] and is dominated by siltstones, mudstones, carbonaceous shales, coals, and subordinated sandstones[18]. The Shotgun Member directly overlies and lithologically merges with the lower member in areas where the Waltman shale is absent[11,19]. The thickness of the Fort Union is relatively unaffected by upwarping and downwarping indicating that downfolding occurred after deposition of the formation. Conglomerates and sandstones of the lower member of the Fort Union were initially targeted as producing zones in the Pavillion Field[18].

Based on gamma ray, resistivity, and combined gamma ray-resistivity logs, Flores and Keighin[18] identified four fluvial depositional systems in the lower member of the Fort Union Formation in the Pavillion Field. Type I reservoirs were characterized as stacked sandstone (up to ~ 18 m thick) with internal scours marked by lag conglomerates formed by low sinuosity side and mid-channel bars. Type II reservoirs were characterized as multistory sandstones (~4 to ~ 9 m thick) separated by siltstone and mudstone seal rocks (~1 to ~6 m thick) formed by low sinuosity cut and fill channels. Type III reservoirs were characterized as multistory sandstones (~2 to ~ 14 m thick) interbedded with siltstones and mudstones (~2 to ~12 m thick) formed by high sinuosity meander channels. Type IV reservoirs were characterized as sandstones (up to ~ 6 m thick) within mudstones and siltstones formed by crevasse splays.

A.4 Lithology of the Wind River Formation

Fluvial deposition of the Wind River Formation occurred during a time of intense folding and uplift during the later stages of the Laramide orogeny[6,11,20,21] resulting in considerable lithological variation of the formation throughout the WRB[20]. Thickness of the Wind River Formation in the basin varies from 0 to about 1524 m[6]. Information from well completion reports and drilling logs indicates that in the Pavillion Field, thickness of the Wind River Formation ranges from 853 to 1228 m. The underlying Paleocene Fort Union Formation ranges in thickness from 762 to 914 m in the area[18].

Keefer[19,20] stated that, in general, two facies predominate in the Wind River Formation throughout the WRB – a coarse boulder facies representative of deposition along mountain slopes and a fine-grained commonly brightly varicolored facies representative of deposition farther out in the basin with gradation of these two facies in overlapping mountain and basin areas. However, depending on the transport power of ancient streams, coarse grained sandstone and conglomerate extend several miles in to the basin in channel deposits.

McGreevy et al.[6] stated that in the Wind River Indian Reservation (WRIR) (an area directly west of the Pavillion Field), oil well logs and test drilling indicated: (1) an upper fine-grained sequence at the surface in most of the eastern part of the reservation consisting primarily of gray and green siltstone, shale, and sandstone with numerous sheet and channel deposits of brown siltstone and sandstone with a maximum thickness of about 244 m in most of the area; (2) a sequence containing many coarse-grained, well sorted, loosely cemented, very porous, largely arkostic sandstone and conglomerated beds of thickness of ~ 305 m but thinning to the northeast part of the WRIR; and (3) a lower sequence consisting of fine-grained brown, maroon, red, and gray siltstone and shale with some sandstone of thickness of several thousand feet which intertongues with the coarse-grained sequence toward the south end of the WRIR.

A continuous sandstone unit, termed the Basal Wind River unit, lies at the base of the Wind River Formation in the Pavillion Field[9,10]. This unit appears frequently in drilling and well completion reports. The continuity of this unit contrasts with substantial vertical and lateral stratigraphic variation in sandstone units over short distances in the Pavillion area[9,10] and throughout the Wind River Formation in general[18,22] precluding mapping of these units using conventional borehole log techniques. Sandstone units are generally characterized as lenticular, discontinuous, and separated by confining shale, mudstone, and siltstone units[6].

Sandstone lenses in the Wind River Formation in the Pavillion field are reported to be generally fine to very fine grained, well sorted, have porosity in the range of 4 to 28 percent and permeability in the range of 0.1 to 300 millidarcies (md)[9]. Referring to development in 14 gas wells and 8 dry holes in the Wind River and Fort Union Formations, Single[9] stated that on average 75 sandstone units (varying in thickness between ~1 to 21 m) were penetrated in each well of which 6 to 20 units were gas productive and the remaining had limited porosity and/or permeability, or were "water bearing". Drilling in the Pavillion field is complicated by the presence of water sensitive shales and petrophysical evaluation is complicated due to the presence of fresh water and pore-filling clays[9].

The central part of the basin, is characterized by stream-valley fill and broad flood plains and that the presence of large quantities of overbank mudstones and near linear channel-sandstone ridges suggest that meandering streams of low sinuosity were dominant during deposition of the Wind River Formation[21]. The Eocene Wind River appears to have flowed directly through an area that is now the Pavillion Field in the vicinity of production well Tribal Unit 14X-11[21]. Maximum intervals of continuous sandstone deposits are greatest near the course of the Eocene Wind River where channel sandstone bodies can be as much as 40 meters thick, but most are much thinner[21].

A.5 Lysite and Lost Cabin Members of the Wind River Formation

In the eastern and northeastern margins of the WRB (north and east of the Pavillion field), the Wind River Formation has been divided into the Lysite and overlying Lost Cabin Member based on lithological and faunal differences[19,20]. Faunal distinction was largely based on the presence of the genus *Lambdotherium* in the Lost Cabin beds and its absence in Lysite beds[20]. In the northeastern portion of the WRB, the Lysite Member consists of yellow to brown sandstone and conglomerate interbedded with red, gray, and greenish-gray sandy claystone and siltstone[20]. The Lost Cabin Member consists of gray, yellow, and brown sandstone with locally prominent beds of conglomerate alternating with violet, red, purple, gray, and green sandy clayey sandstone[20]. Both members contain an abundance of fine-grained strata[19].

One of the primary differences between these two members is the composition of conglomerates. Conglomerate in the Lost Cabin Member contains abundant Precambrian rock fragments of granite and gneiss[19]. Conglomerate in the Lysite Member is derived almost exclusively from Paleozoic formations[19] and contains an abundance of limestone, dolomite, and chert fragments[20]. In the central part of the WRB (where the Pavillion Field is located), there is no sample or electric log basis to separate the Wind River Formation into Lysite and Lost Cabin Members[20]. Throughout the WRB, the name Wind River Formation is applied to all lower Eocene rocks, including the Indian Meadows Formation and the Lost Cabin and Lysite Members of the Wind River Formation because there are no viable criteria for distinguishing individual members of the Wind River Formation from sample and well log data[11,19,20].

Stephens[23] and Itasca Denver Inc.[24] state that the Wind River Formation in the Pavillion field can be divided into the Lost Cabin member and underlying Lysite member and that the former is a source of potable water while the later has total dissolved solids (TDS) levels exceeding 10,000 mg/L. They state that EPA's monitoring well MW01 was completed in the Lower Lost Cabin member, and MW02 was completed in the Upper Lysite Member where elevated chloride was detected. However, neither Stephens[23] nor Itasca Denver Inc.[24] provide any justification (e.g., faunal or lithologic) for identification of these units outside established geographic areas in the WRB.

In available lithologic logs in the Pavillion Field, limestone and dolomite fragments characteristic of the Lysite member were not identified at Tribal 1-21, Tribal 1-22, Taylor Patented 1, Shell 33X-10, Mae H. Rhodes 1, Runners Herford 1, Roland Patented 34-13, Ocean Lake Tribal 1-15, John K. Coolidge 1-4, Unit 12-3, Govt Ocean Lake 1, Doles Unit 44-15, Tribal 21-9, and Tribal Pavillion 14-2 at or below the depth of MW02. Chert fragments were identified at 856 m below ground surface (bgs) at Shell 33X-10 and at 1036 m bgs at Taylor Patented 1.

Also, neither Stephens[23] nor Itasca Denver Inc.[24] provide references or documentation that, even where present, the Lysite member contains TDS levels exceeding 10,000 mg/L. In an evaluation of alternative water supply options for residents in the Pavillion field, Gores and Associates[25] identified three domestic wells of similar depth of MW02 in the immediate vicinity of the Pavillion field at 274, 305, and 322 m bgs with associated TDS concentrations of 631, 590 (775 duplicate), and 607 mg/L TDS respectively. Also, USGS reports (McGreevy et al.[6], Plafcan et al.[26], and Daddow et al.[5]) relevant to the Pavillion area indicate no instance of TDS levels exceeding 10,000 mg/L in the Wind River Formation. Plafcan et al.[26] identified a water supply well at 674 m bgs having a TDS concentration of 1190 mg/L.

A.6 EPA Lithologic Cross-Section through Pavillion Field

EPA[27] used borehole geophysical logs from 32 production wells to develop a lithologic cross-section in the vicinity of MW01 and MW02. Depending upon the specific production well, various combinations of natural gamma, resistivity, self-potential, density, and neutron porosity logs were utilized. No gradational/intermediate values between shale and sandstone (e.g. 80% shale, 20% sandstone) were used although they are known to exist throughout the Wind River Formation. This designation was maintained for consistency for near surface deposits where fine-, medium-, and coarse-grained sandstones could be differentiated from driller's logs. It was generally clear from the various logs whether a specific interval contained sandstone or shale, but not where each layer started or ended. Thus, assignment of boundaries was subjective. Each sandstone or shale layer was represented as having at least one meter in thickness since log resolution was insufficient to discern individual layers less than this resolution.

Data was used to populate a three-dimensional lithology model using a commercial software package Rockware15. A lithologic cross-section (Figure SI A4) developed along a transect (Figure SI A3) represents a slice taken through this 3D model. In general, lithology was highly variable and difficult to correlate from borehole to borehole, even for boreholes in close proximity to one another consistent with the experience of others (e.g., Osiensky et al.[22]). However, it is apparent that there are no laterally continuous confining layers above depths of well stimulation (Figure SI A4). Since the majority of geophysical logs from the oil and gas wells were run after installation of surface casing, the shallow lithology structure (upper 150-200 meters) in the model was dominated by information from the two EPA installed monitoring wells. Thus, the apparent existence of continuous shale units near the surface may be a result of insufficient data rather than physical reality.

The aspect ratio (length versus width) of sandstone lenses cannot be discerned from available data. Itasca Denver Inc.[24] used exposures from Upper Jurassic Salt Wash Sandstone Member of the Morrison Formation in the Henry Mountains area of southern Utah investigated by Robinson and McCabea[28] to define the aspect (length versus width) ratios of sandstone bodies in the Paleocene Fort Union and Eocene Wind River Formations. Justification for this comparison was not provided.

A plot of the entire Pavillion Field is provided in Figure SI A5.

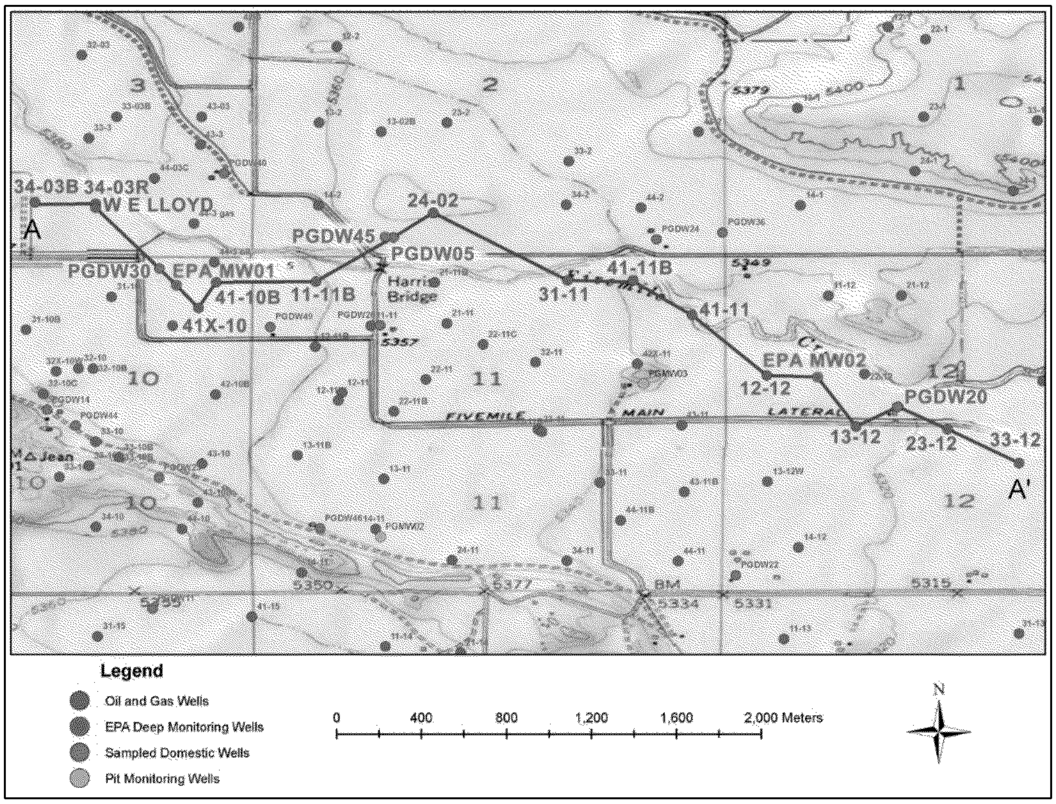

Figure SI A3. Map illustrating transect used to develop a lithologic cross section across the Pavillion Field. From EPA[27]

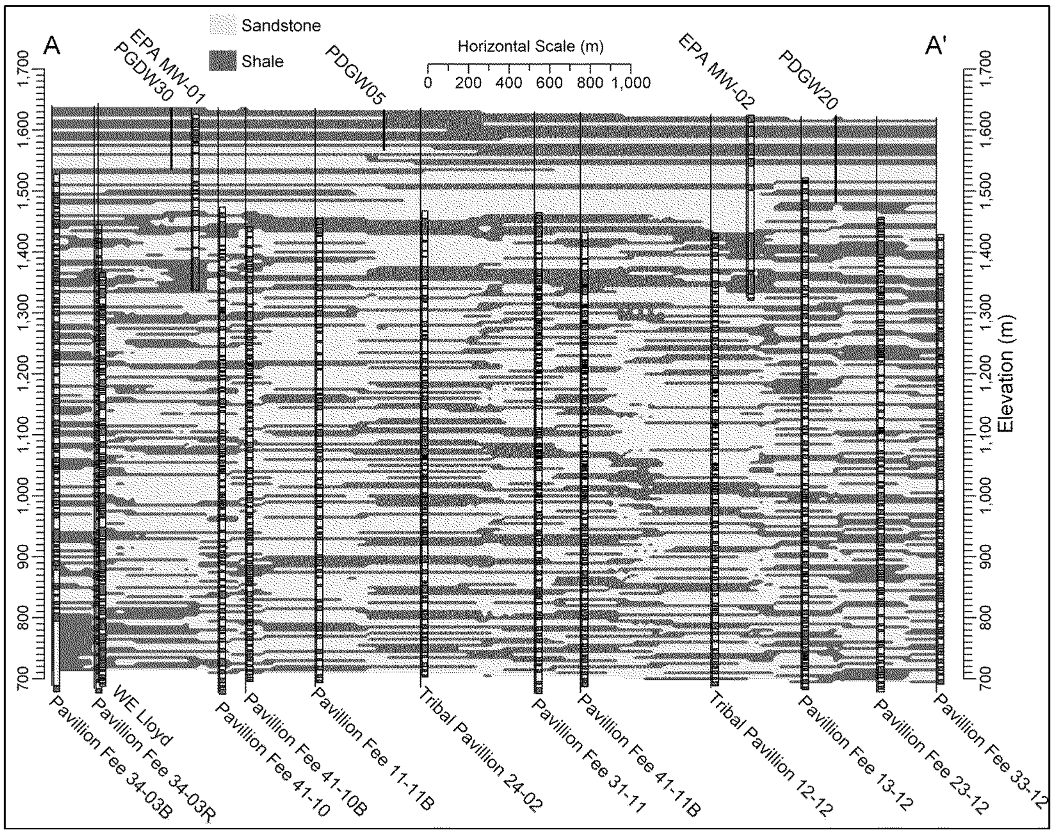

Figure SI A4. Lithologic cross-section along transect illustrating undifferentiated sandstone and shale units. From EPA[27]

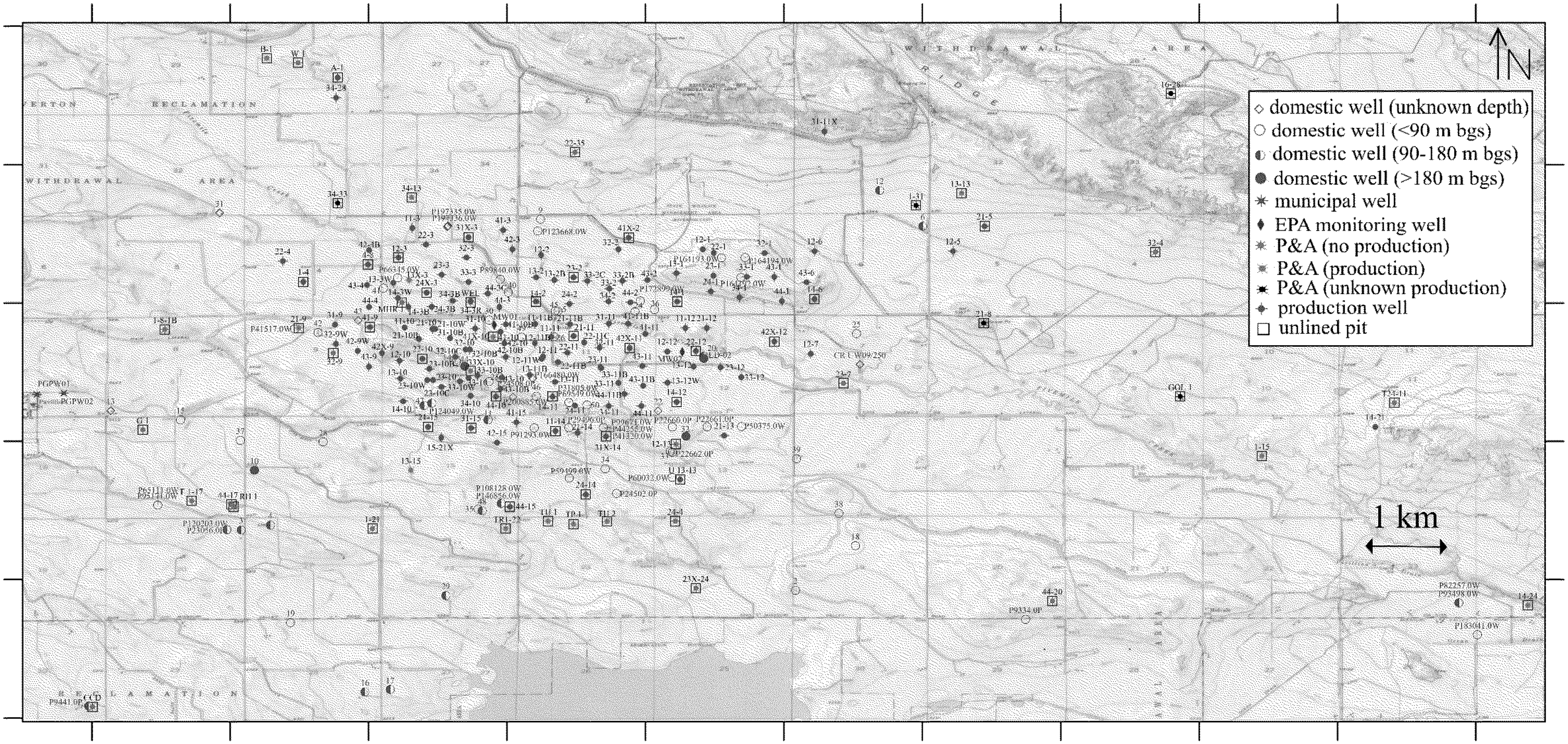

Figure SI A5. Pavillion Field plot illustrating locations of production wells, domestic wells, EPA monitoring wells (MW01 and MW02), and unlined pits. Domestic wells sampled by EPA identified by last two digits of PGDWXX series. Unsampled domestic wells having a Wyoming State Engineer's Office (SEO) permit number identified with the prefix "P." Unsampled domestic wells lacking SEO permits not identified. Depths of domestic well provided in Table SI B1. Full names of production wells, abbreviated here, are provided in Table SI C1. Locations of unlined pits are approximated by locations of associated production wells.

B – Locations, Depths, and Major Ion Concentrations of Domestic Wells in and Around the Pavillion Field

Table SI B1. Location and depth of domestic wells in and surrounding the Pavillion well field. Domestic wells with prefix PGDWXX were sampled by EPA. State Engineers Office (SEO) permit provided when available. PGDW01 and PGDW02 are municipal wells PGPW01 and PGPW02. Information compiled from EPA[27], EPA[29,30], Wyoming Oil and Gas Conservation Commission (WOGCC)[31,32] and Gores and Associates[25]

SEO Permit Number	EPA Well Identification	Latitude	Longitude	Ground Elevation (m AMSL)	Well Depth (m bgs)	Completion Date
?	PGPW01/PGDW07	43.24678802	-108.6879349	1666.0	154.2	?
?	PGPW02/PGDW08	43.24697113	-108.6840515	1641.0	157.0	?
?	PGDW01	43.2185	-108.5783	1610.0	?	?
?	PGDW02	43.21848912	-108.5783117	1629.8	15.2	?
?	PGDW03	43.22721318	-108.6584107	1629.8	137.2	?
?	PGDW04	43.22790909	-108.6541901	1638.3	134.1	?
P32161.0W	PGDW05	43.25884628	-108.6126556	1632.2	64.0	02/02/1976
?	PGDW06	43.27110813	-108.5599211	1663.9	115.8	?
?	PGDW09	43.27211644	-108.615144	1635.6	9.1	?
?	PGDW10	43.2358284	-108.6565018	1633.7	225.6	?
?	PGDW11	43.24312049	-108.6228628	1636.8		?
?	PGDW12	43.27628927	-108.5661502	1652.9	115.8	?
?	PGDW13	43.2444467	-108.6772771	1642.6	?	?
No permit on file	PGDW14	43.25154027	-108.6273311	1642.3	57.9	?
?	PGDW15	43.24312129	-108.6671791	1606.9	30.5	?
?	PGDW16	43.20381363	-108.6405183	1610.9	164.6	?
?	PGDW17	43.20416653	-108.6368713	1615.1	152.4	?
?	PGDW18	43.22491388	-108.569651	1612.7	67.1	?
?	PGDW19	43.21382469	-108.651274	1622.1	19.8	?
No permit on file	PGDW20	43.25230026	-108.5915756	1624.0	140.2	?
No permit on file	LD-02	43.25437	-108.58919	1623.0	185.9	?
?	PGDW22	43.2444191	-108.598175	1627.0	?	?
P24508.0P	PGDW23	43.2486496	-108.6225891	1656.9	53.3	12/31/1964
?	PGDW24	43.25877211	-108.6015059	1622.1	30.5	?
?	PGDW25	43.25558722	-108.5694867	1643.8	24.4	?
?	PGDW26	43.25512275	-108.6132115	1649.9	19.8	?
?	PGDW28	43.23993143	-108.6465688	1612.7	25.9	?
?	PGDW29	43.21773909	-108.6288449	1634.9	121.9	?
No permit on file	PGDW30	43.25753	-108.62258	1637.1	79.2	?
?	PGDW31	43.27302485	-108.6615302	1624.9	?	?
P64110.0W	PGDW32	43.24074936	-108.5941391	1624.9	205.7	5/24/1983
P22662.0P	PGDW33	43.23855522	-108.5964146	1626.1	9.1	12/31/1934
?	PGDW34	43.23605297	-108.6058086	1634.0	30.5	?
?	PGDW35	43.23021564	-108.6241763	1630.1	88.4	?
?	PGDW36	43.25905726	-108.5987059	1641.0	30.5	?
?	PGDW37	43.24016136	-108.6585376	1615.4	24.4	?
?	PGDW38	43.2296203	-108.572037	1610.9	48.8	?
?	PGDW39	43.23750687	-108.5781708	1615.4	17.4	?
?	PGDW40	43.26156616	-108.6198273	1638.0	67.1	?
P66345.0W	PGDW41	43.262146	-108.6378479	1645.0	21.3	1/31/1984
P41517.0W	PGDW42	43.25574493	-108.647316	1645.9	61.0	11/29/1977
?	PGDW43	43.25749207	-108.64151	1645.0	?	?
P24506.0P	PGDW44	43.25086975	-108.6261292	1645.6	228.6	12/31/1932
No permit on file	PGDW45	43.25888062	-108.6130142	1632.5	30.5	?
?	PGDW46	43.24651337	-108.6157684	1638.9	14.6	?
?	PGDW47	43.24520493	-108.6319885	1641.3	147.5	?
?	PGDW48	43.2299881	-108.6235733	1633.1	115.8	?
No permit on file	PGDW49	43.25505829	-108.6178741	1637.7	15.2	?
P166481.0W	PGDW50	43.2453	-108.6085	1633.1	61.0	4/7/2005
CR UW09/250	None	43.25114	-108.56899	1614.4	?	8/19/1977
P108128.0W	None	43.23104	-108.62085	1626.1	115.5	11/5/1997
P120203.0W	None	43.22725	-108.66048	1628.2	137.2	11/8/1999
P123668.0W	None	43.27042	-108.61556	1638.9	18.3	3/6/2000
P124049.0W	None	43.24552	-108.63087	1639.2	147.5	3/6/2000
P146856.0W	None	43.23104	-108.62085	1626.1	115.8	9/5/2002
P164192.0W	None	43.26372	-108.5862	1649.0	24.4	12/6/2004
P164193.0W	None	43.26653	-108.589	1654.1	30.5	12/6/2004

SEO Permit Number	EPA Well Identification	Latitude	Longitude	Ground Elevation (m AMSL)	Well Depth (m bgs)	Completion Date
P164194.0W	None	43.26658	-108.5856	1654.1	31.2	12/6/2004
P166480.0W	None	43.24909	-108.6163	1633.1	?	4/7/2005
P172899.0W	None	43.26029	-108.60075	1631.0	30.5	10/19/2005
P183041.0W	None	43.21207	-108.47977	1567.9	73.2	8/1/2007
P197335.0W	None	43.27103	-108.62861	1645.9	?	1/27/2012
P197336.0W	None	43.27115	-108.62854	1645.9	?	1/27/2012
P200885.0W	None	43.24642	-108.61915	1657.0	?	8/16/2013
P22660.0P	None	43.24208	-108.59609	1624.9	53.3	9/30/1938
P22661.0P	None	43.24212	-108.5911	1622.1	14.6	8/31/1947
P22662.0P	None	43.23844	-108.59611	1625.5	9.1	12/31/1934
P23056.0P	None	43.22725	-108.66048	1628.2	19.8	1/4/1960
P24502.0P	None	43.23248	-108.60418	1628.9	54.9	12/31/1942
P24506.0P	None	43.24918	-108.62593	1658.4	228.6 12	/31/1932
P24508.0P	None	43.2492	-108.62099	1637.1	53.3	12/31/1964
P29496.0P	None	43.24198	-108.61107	1633.1	39.6	3/31/1975
P30217.0W	None	43.24311	-108.62275	1633.1	106.7 6/	18/1975
P31805.0W	None	43.24562	-108.61107	1633.1	30.5	1/20/1976
P34936.0W	None	43.24311	-108.62275	1633.1	106.7 9/	14/1976
P41320.0W	None	43.24201	-108.60608	1642.9	30.5	12/19/1977
P41517.0W	None	43.25628	-108.6507	1644.1	61.0	11/29/1977
P44255.0W	None	43.24201	-108.60608	1642.9	68.6	7/18/1978
P50375.0W	None	43.24216	-108.58612	1618.0	30.5	10/15/1979
P59499.0W	None	43.23471	-108.611	1622.1	33.5	2/3/1982
P60032.0W	None	43.2348	-108.59614	1618.0	26.2	3/23/1982
P65111.0W	None	43.23078	-108.67048	1645.0	27.4	8/3/1983
P66345.0W	None	43.26365	-108.6358	1642.9	21.3	1/31/1984
P69549.0W	None	43.24562	-108.61107	1633.1	30.5	2/25/1985
P82257.0W	None	43.21668	-108.48244	1571.8	91.4	4/20/1990
P89840.0W	None	43.26343	-108.62097	1639.5	65.5	9/17/1992
P91293.0W	None	43.24195	-108.61606	1631.0	3.0	4/5/1993
P9334.0P	None	43.21429	-108.54506	1625.5	6.1	12/31/1935
P93498.0W	None	43.21668	-108.48244	1571.8	69.5	11/15/1993
P9441.0P	None	43.20178	-108.68044	1634.9	177.4 1/1	/1944
P95171.0W	None	43.23078	-108.67048	1645.0	25.9	5/9/1994
P99671.0W	None	43.24201	-108.60608	1643.0	16.7	6/28/1995
P14914P	None	?	?	?	39.6	?
P98757W	None	?	?	1670.0	156.1	?
P58929W	None	?	?	1652.0	17.4	?
P34345W	None	?	?	1667.9	150.9	?
P59104W	None	?	?	1667.9	152.4 ?	
P24507P	None	?	?	1647.1	228.6 ?	
P97501W	None	?	?	1624.0	?	?
P30217W	None	?	?	?	106.7 ?	
P182983W	None	?	?	1638.6	231.6 ?	
P46362W	None	?	?	1642.3	54.9	?
P62641W	None	?	?	1662.7	208.8 ?	
P53567W	None	?	?	1652.0	42.7	?
P25636W	None	?	?	1633.7	12.5	?
P110443	None	?	?	1633.7	127.1 ?	
P28496W	None	?	?	1613.3	11.0	?
P26200W	None	?	?	1603.2	88.4	?
P40603W	None	?	?	1619.1	12.2	?
P76475W	None	?	?	1621.5	97.5	?
P14548P	None	?	?	1615.4	18.3	?
P30162W	None	?	?	1645.9	61.0	?
P32163W	None	?	?	1639.8	114.3 ?	
P9941P	None	?	?	1637.1	177.4 ?	
P116598W	None	?	?	1629.8	143.3 ?	
P25011W	None	?	?	1627.6	88.4	?
P177246W	None	?	?	1611.5	304.8 ?	
P190223W	None	?	?	1618.2	321.6 ?	
P191733W	None	?	?	1606.9	274.3 ?	
Unidentified (16 domestic wells)	None	?	?	?	?	?

Table SI B2. Major ion concentrations in water sampled from domestic wells.

Well Name	Date	pH	SC (µS/cm)	Alkalinity (mg/L) (CaCO3)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Br (mg/L)	Cl (mg/L)	SO4 (mg/L)	F (mg/L)	NO_3 (N) (mg/L)	Fe (mg/L)	TDS (mg/L)	Source
PGDW05	Mar-09	9.02	956	93.3	192	0.286	3.6	0.127	NM	17.0	295	0.9	<0.5	0.187		EPA[29]
	Jan-10	8.22	900	88.4	189	<5.0	3.33	<5.0	NM	16.5	287	0.9	<0.3	0.0666		EPA[30]
	Apr-11	9.06	820	80	190	0.24	3.35	0.08	NM	16.8	276	1.2	<0.014	0.124		EPA[27]
	Apr-12	9.30	837	91	190	0.47	3.17	0.07	<1.00	16.8	308	0.90	0.02	<0.03		EPA[33]
	Jun-14	9.29	878	92	220	<0.1	3.4	<0.5	0.093	19	310	1.0	<0.005	<0.1	560	WYDEQ[34]
	Aug-14	9.09	969	97	170	0.37	3.5	0.11	0.099	18	300	0.92	<0.005	0.034	560	WYDEQ[34]
PGDW06	Mar-09	10.2	1262	34.9	249	0.344	7.11	0.0342	NM	31.0	485	1.3	<0.5	NM		EPA[29]
PGDW09	Mar-09	8.35	1128	254	233	2.05	16.6	4.14	NM	10.5	279	2.4	3.2	NM		EPA[29]
PGDW11	Mar-09	7.17	3400	312	423	5.53	363	80.9	NM	15.3	1780	0.2	1.3	NM		EPA[29]
PGDW12	Mar-09	10.04	1344	37.1	256	0.567	7.78	0.424	NM	30.8	497	1.5	<0.5	0.695		EPA[29]
PGDW14	Mar-09	7.85	2990	159	690	4.51	154	18.1	NM	26.1	1820	0.4	0.7	NM		EPA[29]
	Apr-11	7.73	3473	156	753	3.52	154	18.6	NM	23.7	1760	<0.05	0.36	<0.019		EPA[27]
	Jun-14	7.65	3920	160	820	3.5	170	19	0.29	29	2000	<0.40	0.44	<0.1	2930	WYDEQ[34]
	Aug-14	7.62	4110	160	700	4.4	140	18	<0.15	28	1900	0.25	0.38	<0.1	2910	WYDEQ[34]
PGDW20	Mar-09	8.76	2005	70.2	520	1.01	79.3	9.33	NM	34.5	1370	0.8	<0.5	0.0342		EPA[29]
	Jan-10	8.89	2690	67.9	550	<5.0	71.7	8.14	NM	32.6	1270	0.8	<0.3	0.300		EPA[30]
	Oct-10	8.85	2940	54	562	1.05	71.9	8.12	NM	33	1320	0.90	0.35	0.221		EPA[27]
	Apr-11	8.59	2430	102	520	0.780	63	6.86	NM	22.9	1150	1.3	<0.03	0.137		EPA[27]
	Apr-12	8.89	2429	66	491	1.64	57.9	5.93	<1.00	32.3	1130	0.94	0.073	<0.03		EPA[33]
	Jun-14	8.84	2880	83	630	0.72	78	7.6	<0.15	35	1300	0.92	<0.03	0.12	1990	WYDEQ[34]
	Aug-14	8.75	2980	83	520	0.91	82	8	0.13	35	1300	0.89	<0.01	0.088	2050	WYDEQ[34]
LD02	Oct-10	8.94	1175	78	313	0.57	25.2	1.43	NM	20.1	698	2.28	<0.10	0.023		EPA[30]
	Jun-14	8.29	3610	56	680	1.8	140	21	<0.15	38	1700	1.5	<0.25	0.079	2500	WYDEQ[34]
	Aug-14	NM	NM	62	630	1.6	130	22	<0.15	37	1700	1.5	<0.25	<0.0076	2560	WYDEQ[34]
PGDW22	Mar-09	6.93	6180	332	837	8.99	416	126	NM	79.9	2720	<0.2	43.6	NM		EPA[29]
	Jan-10	7.06	4230	337	908	5.83	397	130	NM	74.6	2780	<0.2	40.7	<0.1		EPA[30]
PGDW23	Mar-09	9.43	816	61.4	208	0.278	6.51	0.070	NM	19.8	365	1.2	<0.5	NM		EPA[29]
	Jan-10	9.72	780	54.2	194	<5.0	5.82	<5.0	NM	19.7	368	1.5	<0.3	<0.100		EPA[30]
	Apr-11	9.07	959	72	208	0.31	6.7	0.17	NM	19.9	365	1.6	<0.03	<0.019		EPA[27]
	Apr-12	9.13	996	65	223	0.61	7.19	0.09	<1.00	19.0	397	0.98	0.05	<0.03		EPA[33]
	Jun-14	9.28	1110	57	240	0.11	6.2	<0.5	0.14	22	400	1.5	0.03	<0.1	650	WYDEQ[33]
	Aug-14	9.09	1040	60	200	0.37	7.4	0.083	0.11	21	380	1.5	<0.005	<0.0076	650	WYDEQ[33]
PGDW24	Mar-09	7.65	4700	165	938	7.02	327	131	NM	55.7	3200	0.6	<0.5	0.995		EPA[29]
PGDW25	Mar-09	8.68	972	205	249	1.05	10.9	1.05	NM	8.4	355	4.1	<0.5	0.0517		EPA[29]
	Jan-10	7.94	1511	295	269	<5.0	70.1	9.63	NM	9.5	441	<0.2	1.7	<0.100		EPA[30]
PGDW26	Mar-09	7.13	2390	337	220	6.8	364	57.7	NM	14.6	1240	0.7	1.5	NM		EPA[29]
	Apr-11	6.95	2390	196	232	5.15	334	56	NM	13.2	1180	1	1.37	<0.019		EPA[27]
PGDW28	Mar-09	8.3	1170	258	239	2.15	40.6	12.9	NM	16.7	298	0.5	3.7	NM		EPA[29]
PGDW30	Mar-09	9.6	902	95.7	210	0.294	4.29	0.125	NM	16.3	335	0.9	<0.5	0.117		EPA[29]
	Jan-10	9.39	967	94.0	195	<5.0	4.05	<5.0	NM	15.5	333	0.9	<0.3	0.0441		EPA[30]
	Oct-10	9.24	1068	78.0	208	0.2	4.3	0.10	NM	15.2	357	1.0	0.23	<0.019		EPA[27]
	Apr-11	8.92	938	82	210	0.29	4.5	0.09	NM	16.1	327	1.1	<0.03	0.042		EPA[27]
	Apr-12	8.98	954	91	213	0.55	4.42	0.1	<1.00	16.1	337	1.05	0.02	<0.03		EPA[33]
	Jun-14	9.19	1040	97	240	0.18	4.3	<0.5	0.11	17	360	0.91	R	<0.1	630	WYDEQ[34]
	Aug-14	8.84	1040	96	240	0.33	4.5	0.1	0.080	17	340	0.87	<0.005	<0.0076	640	WYDEQ[34]

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Well Name	Date	pH	SC (µS/cm)	Alkalinity (mg/L) (CaCO3)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Br (mg/L)	Cl (mg/L)	SO4 (mg/L)	F (mg/L)	NO_3 (N) (mg/L)	Fe (mg/L)	TDS (mg/L)	Source
PGDW31	Mar-09	8.6	2006	82.5	435	0.901	31.2	0.843	NM	13.3	1030	0.4	0.5	NM		EPA[29]
PGDW32	Mar-09	10.47	908	34.1	199	0.267	7.16	0.017	NM	21.8	373	2.3	<0.5	0.412		EPA[29]
	Jan-10	9.87	1018	31.5	193	<5.0	6.89	<5.0	NM	21.4	368	2.4	<0.3	0.125		EPA[30]
	Apr-11	9.3	885	46	198	0.09	7.2	0.03	NM	18.8	361	2	<0.03	0.024		EPA[27]
	Jun-14	9.97	1110	30	230	<0.1	7.4	<0.02	<0.03	24	400	2.5	<0.005	<0.1	620	WYDEQ[34]
	Aug-14	9.88	1120	34	190	0.42	8	0.038	0.036	22	380	2.3	<0.005	<0.0076	640	WYDEQ[34]
PGDW33	Mar-09	7.77	1662	276	178	4.99	228	40.9	NM	23.0	2690	0.2	2.1	NM		EPA[29]
	Jun-14	7.05	1860	310	150	3.8	200	39	<0.03	20	700	0.65	3.2	0.087	1350	WYDEQ[34]
	Aug-14	7.21	1700	260	160	3	150	27	0.043	18	590	0.98	2.0	<0.0076	1180	WYDEQ[34]
PGDW34	Mar-09	7.87	4480	373	786	7.4	325	113	NM	28	670	0.5	3.5	NM		EPA[29]
PGDW35	Mar-09	8.63	2810	84.0	587	1.09	118	1.1	NM	24.1	1610	0.3	0.5	1.10		EPA[29]
PGDW36	Mar-09	7.62	649	232	41.7	2.58	89.5	28.9	NM	3.2	195	1.0	1.2	NM		EPA[29]
PGDW37	Mar-09	8.14	819	342	187	0.887	12.1	1.3	NM	8.7	89.9	0.9	1.2	NM		EPA[29]
PGDW39	Jan-10	7.79	6410	129	1110	5.28	389	147	NM	52.9	3640	0.3	<0.3	0.33		EPA[30]
PGDW40	Jan-10	9.06	1229	86.3	244	<5.0	6.57	<5.0	NM	13.1	426	<0.2	<0.3	1.26		EPA[30]
PGDW41A	Jun-14	7.22	7680	320	1400	6.2	670	56	<0.30	710	3200	0.15	21	<0.1	5840	WYDEQ[34]
	Aug-14	7.07	8080	340	1300	5.4	580	54	<0.30	850	3100	0.17	17	0.0090	6350	WYDEQ[34]
PGDW41B	Jan-10	7.63	4470	108	1030	2.68	270	57.5	NM	31.4	2670	0.5	<0.3	1.88		EPA[30]
	Apr-11	7.05	4866	112	896	3.18	452	46.9	NM	97.6	2640	<0.05	17.5	<0.019		EPA[27]
	Jun-14	7.07	5240	130	980	4.3	290	55	<0.15	35	2800	0.44	<0.03	0.56	4170	WYDEQ[33]
	Aug-14	7.61	5270	140	920	3.4	270	61	<0.30	34	2700	0.39	0.18	0.55	4220	WYDEQ[33]
PGDW42	Jan-10	9.18	888	88.5	181	<5.0	5.06	<5.0	NM	13.2	311	1.0	<0.3	0.0966		EPA[30]
PGDW43	Jan-10	8.19	4410	113	911	<5.0	208	13.7	NM	38.4	2470	0.4	<0.3	0.403		EPA[30]
PGDW44	Jan-10	8.13	4080	100	994	<5.0	259	28.3	NM	39.5	2880	0.3	<0.3	2.07		EPA[30]
	Apr-11	8.17	4730	94	1060	2.09	259	19.2	NM	32.1	2900	<0.05	<0.03	2.06		EPA[27]
	Jun-14	8.11	5680	81	1100	2.2	290	20	<0.15	45	3100	0.34	<0.03	2.4	4420	WYDEQ[34]
	Aug-14	8.28	5900	80	1000	2.8	250	21	<0.15	44	2900	0.22	<0.03	3	4440	WYDEQ[34]
PGDW45	Jan-10	7.63	1103	379	59.4	2.61	138	31.2	NM	14.5	213	1.9	0.3	<0.100		EPA[30]
	Apr-11	6.85	1085	364	61.6	2.81	159	34.5	NM	18.4	25 1.	1.7	0.64	<0.019		EPA[27]
	Jun-14	7.17	1310	350	97	2.7	160	35	0.19	31	330	2.0	1.4	<0.0076	820	WYDEQ[34]
	Aug-14	7.01	1150	360	79	3	120	32	0.24	36	250	1.7	0.98	<0.0076	740	WYDEQ[34]
PGDW46	Jan-10	7.79	855	329	91.1	1.81	90.3	9.89	NM	8.4	126	0.5	2.3	<0.100		EPA[30]
PGDW47	Jan-10	9.52	970	44.1	183	<5.0	6.87	<5.0	NM	21.6	330	1.5	<0.3	<0.100		EPA[30]
PGDW48	Jan-10	8.21	3550	89.8	725	<5.0	147	4.35	NM	24.1	1840	0.3	<0.3	0.0491		EPA[30]
PGDW49	Jan-10	7.66	5470	243	1210	11.4	486	153	NM	64.3	3160	0.4	7.7	11.4		EPA[30]
	Apr-11	7.34	5333	296	982	9.66	417	127	NM	54.3	3200	<0.05	8.75	2.41		EPA[27]
	Jun-14	7.31	5840	330	990	10	430	140	0.20	68	3500	0.58	6.0	0.084	5340	WYDEQ[34]
	Aug-14	7.09	6190	310	960	11	420	130	0.19	61	3300	0.46	4.4	0.18	5220	WYDEQ[34]
PGDW50	Apr-12	8.04	5922	33	1290	3.04	314	12.8	<1.42	57.8	3470	<0.20	<0.008	<0.03		EPA[33]
PGPW01	Mar-09	8.85	1016	60.6	213	0.287	8.85	0.0847	NM	15.7	390	1.2	<0.5	0.0793		EPA[29]
	Jan-10			74.7	173	<5.0	5.7	<5.0	NM	15.3	300	1.2	<0.3	0.112		EPA[30]
PGPW02	Mar-09	8.57	1883	82.9	390	0.643	36.7	0.240	NM	8.9	857	0.5	<0.5	0.283		EPA[29]
	Jan-10			82.8	393	<5.0	34.4	<5.0	NM	8.5	847	0.5	<0.3	0.255		EPA[30]
	Apr-12	8.46	1856	77	414	0.92	34.7	0.24	<1.00	8.51	886	<0.20	0.14	0.11		EPA[33]
PGDW01	Mar-09			234	808	6.15	398	93.6	NM	34.3	1860	0.4	6.2	NM		EPA[29]

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Well Name	Date	pH	SC (µS/cm)	Alkalinity (mg/L) (CaCO3)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Br (mg/L)	Cl (mg/L)	SO4 (mg/L)	F (mg/L)	NO_3 (N) (mg/L)	Fe (mg/L)	TDS (mg/L)	Source
PGDW02	Mar-09	8.11	551	108	85.8	1.8	34.8	5.32	NM	2.6	175	0.7	<0.5	NM		EPA[29]
PGDW03	Mar-09	9.37	1333	39.5	272	0.403	16.3	0.266	NM	25.1	549	0.9	<0.5	0.0147		EPA[29]
	Jan-10	8.71	1390	28.0	251	<5.0	16.3	<5.0	NM	20.7	570	0.8	<0.3	<0.100		EPA[30]
PGDW04	Mar-09	9.17	1370	28.7	270	0.384	18	0.12	NM	21.6	551	0.9	<0.5	NM		EPA[29]
	Jan-10	9.07	1388	38.3	265	<5.0	15.5	<5.0	NM	23.3	532	0.9	<0.3	<0.100		EPA[30]
PGDW10	Mar-09	8.95	948	147	204	0.394	6.13	0.133	NM	8.0	293	0.9	<0.5	NM		EPA[29]
	Mar-09	8.62	985	147	204	0.400	6.10	0.132	NM	8.0	289	0.9	<0.3	NM		EPA[29]
	Jan-10	8.62	147	147	195	<5.0	5.76	<5.0	NM	7.5	293	0.9	<0.3	<0.100		EPA[30]
PGDW13	Mar-09	6.89	1155	303	196	1.85	61	19.9	NM	6.2	343	0.7	1.0	NM		EPA[29]
PGDW15	Mar-09	7.48	1728	277	269	1.24	72.2	10.2	NM	9.9	520	0.6	1.8	0.274		EPA[29]
PGDW16	Mar-09	9.3	1011	145	188	0.312	6.42	0.0815	NM	13.4	258	0.8	<0.5	NM		EPA[29]
PGDW17	Mar-09	9.61	1490	21.2	278	0.418	21.2	0.527	NM	49.5	583	2.0	<0.5	0.0204		EPA[29]
PGDW18	Mar-09	8.87	2002	20.5	509	0.827	84.5	0.279	NM	27.0	1380	1.8	0.5	NM		EPA[29]
PGDW19	Mar-09	7.75	707	291	194	1.36	29	3.24	NM	6.9	196	0.9	2.6	NM		EPA[29]
PGDW29	Mar-09	9.72	1442	52.3	298	0.417	19.7	0.46	NM	24.6	596	0.9	<0.5	NM		EPA[29]
PGDW38	Mar-09	8.68	2030	46.9	373	2.28	70	2.3	NM	46.9	908	1.3	5.9	0.018		EPA[29]
unidentified			1340		210						860				884	Gores & Assoc.[25]
unidentified											300				580	Gores & Assoc.[25]
unidentified			2180		459						990				1540	Gores & Assoc.[25]
P14914P			2810		362						945				2150	Gores & Assoc.[25]
P98757W			1261		255						439				813	Gores & Assoc.[25]
unidentified			1400		203						480				994	Gores & Assoc.[25]
P58929W			1250												825	Gores & Assoc.[25]
P34345W					190						400				680	Gores & Assoc.[25]
P59104W					210						460				644	Gores & Assoc.[25]
unidentified			974		210						345				647	Gores & Assoc.[25]
P24507P											2900				4250	Gores & Assoc.[25]
unidentified			913		174						320				570	Gores & Assoc.[25]
unidentified					447						1110				1750	Gores & Assoc.[25]
P97501W					555						1161				4010	Gores & Assoc.[25]
unidentified			457		38						67				302	Gores & Assoc.[25]
P30217W											2700				4180	Gores & Assoc.[25]
unidentified											827				1290	Gores & Assoc.[25]
P182983W			886												585	Gores & Assoc.[25]
unidentified			1140												752	Gores & Assoc.[25]
P46362W					140						1100				1550	Gores & Assoc.[25]
P62641W					970						2200				3550	Gores & Assoc.[25]
unidentified											2140				3100	Gores & Assoc.[25]
unidentified											642				1300	Gores & Assoc.[25]
P53567W					175						84				384	Gores & Assoc.[25]
P25636W											750				2070	Gores & Assoc.[25]
P110443			1539		298						570				1010	Gores & Assoc.[25]
unidentified					454						620				1800	Gores & Assoc.[25]
P28496W											29				288	Gores & Assoc.[25]
P26200W											2610				3880	Gores & Assoc.[25]

Well Name	Date	pH	SC (µS/cm)	Alkalinity (mg/L) (CaCO3)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Br (mg/L)	Cl (mg/L)	SO4 (mg/L)	F (mg/L)	NO_3 (N) (mg/L)	Fe (mg/L)	TDS (mg/L)	Source
unidentified			2160		445						988				1530	Gores & Assoc.[25]
unidentified			3790		339						2310				3510	Gores & Assoc.[25]
P40603W											210				710	Gores & Assoc.[25]
P76475W			1320		260						540				808	Gores & Assoc.[25]
P14548P											1049				1690	Gores & Assoc.[25]
P30162W											169					Gores & Assoc.[25]
P32163W											690				1130	Gores & Assoc.[25]
P9941P			2720		579						1290				2040	Gores & Assoc.[25]
P116598W					229						119				376	Gores & Assoc.[25]
unidentified											296				930	Gores & Assoc.[25]
P25011W											2400				3560	Gores & Assoc.[25]
P177246W			1180		248						457				775	Gores & Assoc.[25]
			1180		126						237				590	Gores & Assoc.[25]
P190223W			920												607	Gores & Assoc.[25]
P191733W			956												631	Gores & Assoc.[25]

NM – not measured

C – Summary of Production Well Construction and Stimulation

Table SI C1. Production well construction summary (listed in order of completion date). Information retrieved from well completion reports using API number

API Number	Well Name	Abbreviation	Latitude	Longitude	Completion Date	Year Plugged & abandoned	Ground Elevation (m AMSL)	Total Depth (m)	Depth to Fort Union (m bgs)	Surface Casing (m bgs)	Top of Primary Cement (m bgs)	Mud Filled Interval Below Surface Casing (m)	Drilling Mud
49-013-06388	Mae H. Rhodes 1	MHR 1	43.26009	-108.63519	12/31/1953	1953	1642.0	3,353	1041.8	156.7	541	2812	"Chem Gel"
49-013-06357	Ora Wells 14-12	14-12	43.24571	-108.59549	8/7/1960	---	1622.8	1,983	1048.5	190.5	191	1	Invert
49-013-06359	Govt 23-7	23-7	43.24841	-108.57139	5/1/1961	1961	1612.7^{G}	2,450	?	176.2	1960	1784	Q-Broxin Gel
49-013-06474	Wirth 1	W 1	43.29472	-108.65019	10/22/1961	1961	1680.7	2,899	984.5	200.9	None^{B}	2698	"Gel"
49-013-06395	Tribal Pavillion 23-2	23-2	43.26371	-108.61039	12/3/1962	---	1631.9	1,585	1027.5	195.1	195	0	Invert
49-013-06451	Shell Govt 22-35	22-35	43.28179	-108.61019	2/23/1963	1963	1657.5^{G}	1,676	?	189.6	None^{B}	1486	Invert
49-013-06358	Govt-Ocean Lake 1	GOL 1	43.24649	-108.52271	6/11/1963	1974	1599.0^{G}	1,829	1219.2	177.7	533	355	Invert
49-013-06389	Tribal Pavillion 14-1	14-1	43.26021	-108.59541	6/18/1963	---	1631.6	1,254	1141.2	205.4	222	17	Invert
49-013-06376	Govt 21-8	21-8	43.25711	-108.55111	7/1/1963	?	1629.5^{G}	1,372	1096.7	189.3	?^{E}	?	Invert
49-013-06413	21-5	21-5	43.27111	-108.55099	7/13/1963	---	1626.7	1,524	1125	192.3	655^{R}	463	Invert
49-013-06341	Unit 13-13	U 13-13	43.23449	-108.595	7/16/1963	---	1617.9^{G}	1,411	?	190.2	?^{E}	?	Invert
49-013-06392	Tribal Pavillion 14-6	14-6	43.26056	-108.57556	7/16/1963	---	1641.0^{G}	1,219	?	184.7	?^{E}	?	Invert
49-013-06402	Govt 32-4	32-4	43.26739	-108.52629	7/18/1963	1963	1627.0	1,524	?	188.1	None^{B}	1336	Invert
49-013-06336	Unit 24-14	24-14	43.23231	-108.60861	11/22/1963	---	1617.0	1,159	1121.7	186.8	396	209	Invert
49-013-06273	Govt 44-20	44-20	43.21694	-108.54119	3/16/1964	1964	1642.2^{G}	1524	?	187.4	None^{B}	1337	Invert
49-013-06281	Woodring 23X-24	23X-24	43.21879	-108.59271	4/25/1964	1964	1598.1	1,250	?	184.4	None^{B}	1066	Invert
49-013-08017	Runner Herfords 44-17	44-17	43.23091	-108.65981	5/23/1964	1964	1631.9	1,292	?	183.8	None^{B}	1108	Invert
49-013-06424	Govt 34-33	34-33	43.27444	-108.64449	5/27/1964	?	1652.9^{G}	1,558	?	183.8	?^{E}	?	Invert
49-013-06363	Govt Tribal 33X-10	33X-10	43.25019	-108.62528	12/26/1964	1983	1643.2	5,863	1025.7	67.4	4023	2787^{I}	Invert
49-013-06387	Tribal Pavillion 24X-3	24X-3	43.26151	-108.63161	11/30/1965	---	1641.7	1,492	1002.2	188.1	947^{R}	759	Invert
49-013-06355	14-11	14-11	43.24649	-108.61341	12/10/1965	---	1633.1^{G}	1,503	?	185.3	?^{E}	?	Invert
49-013-06917	IND 13-13	13-13	43.27589	-108.55431	1/20/1966	?	1637.1^{G}	1,177	?	186.8	?^{R}	?	"Chem Gel"
49-013-20062	Tribal Pavillion 31-15	31-15	43.24194	-108.62519	2/26/1968	---	1632.2	1,050	?	205.7	?^{N}	?	Invert
49-013-20084	Maxson 32-9	32-9	43.25278	-108.64511	5/27/1968	1968	1642.9	1,070	1057	187.8	None^{B}	882	Invert
49-013-20298	W. E. Lloyd	WEL	43.26011	-108.62528	2/23/1972	1981	1639.2	4,747	1025.7	277.7	?^{N}	?	"Chem Gel"
49-013-20414	Unit 41X-10	41X-10	43.25511	-108.62201	1/29/1973	1981	1635.6	1,538	1024.1	188.7	418^{P}	229	Invert
49-013-20454	IND 14-20-258 41X-2	41X-2	43.26944	-108.60241	11/29/1973	---	1640.1	1,526	1072.9	185.0	?^{A}	?	Invert
49-013-20457	Tribal Pavillion 31X-3	31X-3	43.26949	-108.62556	12/27/1973	---	1644.1	1,569	1028.4	188.4	35	0	Invert
49-013-20442	W.H. Paul Patent 42X-11	42X-11	43.25349	-108.60231	1/19/1974	---	1627.9	1,533	1016.5	183.2	?^{A}	?	Invert
49-013-20443	Unit 42X-12	42X-12	43.25444	-108.58139	1/19/1974	---	1631.0	1,509	1054.6	184.4	?^{A}	?	Invert
49-013-20456	Unit 31X-14	31X-14	43.24071	-108.60569	1/19/1974	---	1629.2	1,569	1058	185.0	?^{A}	?	Invert
49-013-0491	Clair C Day	CCD	43.20167	-108.67991	5/16/1974	1974	1634.9	2445	1030.2	194.5	None^{B}	2251	Invert
49-013-20581	TR1-22	TR1-22	43.22741	-108.62019	2/7/1976	1986	1622.8	1,280	1104	186.5	793	607	Invert
49-013-20586	Tribal 1-21	1-21	43.22741	-108.63944	3/17/1976	1976	1627.0	1,209	1173.5	190.5	None^{B}	1019	Invert
49-013-20598	Taylor Patented 1	TP 1	43.22806	-108.61041	5/14/1976	?	1610.0	1,222	?	127.4	?^{N}	?	Invert
49-013-20602	Tribal 1-31	1-31	43.27409	-108.56089	7/23/1976	1977	1631.6	1,174	1138.1	125.3	?^{N}	?	Invert
49-013-20654	Tribal Unit 1	TU 1	43.22849	-108.61409	11/3/1976	1982	1613.3	1,119	1082.3	200.3	<549	<349	Invert
49-013-20668	Blankenship Fee 4-8	4-8	43.26556	-108.64009	3/25/1977	---	1647.1	1,586	?	135.3	564^{R,P}	429	Invert
49-013-20700	Roland Patented 34-13	34-13	43.27528	-108.63379	8/31/1977	?	1615.4	1,981	1228.3	147.2	?^{N}	?	Invert
49-013-20748	Shoshone-Arapahoe 24-11	T24-11	43.24556	-108.49179	5/13/1978	1978	1608.1^{G}	4,564	?	457.8	None^{B}	4106	Invert

API Number	Well Name	Abbreviation	Latitude	Longitude	Completion Date	Year Plugged & abandoned	Ground Elevation (m AMSL)	Total Depth (m)	Depth to Fort Union (m bgs)	Surface Casing (m bgs)	Top of Primary Cement (m bgs)	Mud Filled Interval Below Surface Casing (m)	Drilling Mud
49-013-20775	Tribal 24-4	24-4	43.22849	-108.59569	5/22/1978	1978	1622.1	1,216	1099.7	120.7	None^{B}	1095	Invert
49-013-20764	Doles Unit 44-15	44-15	43.23056	-108.61959	6/2/1978	---	1629.5	1,638	1123.5	189.6	198	8	Invert
49-013-20854	Unit 21-11	21-11	43.25521	-108.61039	3/14/1979	---	1632.2	1,555	1021.1	187.5	466	279	Invert
49-013-20855	Tribal Pavillion 12-13	12-13	43.239720	-108.595768	5/12/1979	2001	1624.0	1,646	1090.3	175.6	290	114	Invert
49-013-20875	USA Tribal 258 41-9	41-9	43.25651	-108.63981	8/24/1979	---	1641.3	1,585	?	184.1	274	90	Invert
49-013-08274	Tribal Unit 2	TU 2	43.22841	-108.60556	8/24/1979	1979	1611.5	1,309	?	199.6	838	638	Invert
49-013-20876	USA Tribal 258 22-10	22-10	43.25194	-108.63222	10/13/1979	---	1648.4	1,570	1024.1	185.3	550	365	Invert
49-013-20965	Garrett 1	G 1	43.24167	-108.67261	10/31/1979	1979	1644.1	1,675	?	200.9	None^{B}	1474	Invert
49-013-20889	USA Tribal 258 21-15	21-15	43.24209	-108.63139	12/6/1979	---	1632.8	1,585	1058	188.7	?^{A,R,P}	?	Invert
49-013-20879	Unit 44-10	44-10	43.24649	-108.62161	12/17/1979	---	1642.6	1,585	1027.2	184.4	585	401	Invert
49-013-20878	Unit 22-12	22-12	43.253096	-108.593332	1/17/1980	---	1622.8	1,585	1033.6	178.6	?^{A}	?	Invert
49-013-20857	Tribal Unit 238 11-14	11-14	43.24151	-108.61299	2/5/1980	---	1628.5	1,600	1031.1	184.1	?^{N}	?	Invert
49-013-21026	Tribal Pavillion 16-28	16-28	43.29028	-108.52409	7/16/1980	?	1612.7^{G}	1,386	?	163.1	?^{N}	?	KCl polymer
49-013-21086	Finayson 1-17	F 1-17	43.23139	-108.66556	9/7/1980	1980	1645.0	1,710	1121.7	190.5	None^{B}	1520	Invert
49-013-21128	Tribal Pavillion 14-2	14-2	43.26021	-108.61583	5/28/1981	---	1634.9^{G}	1,577	1007.1	182.6	677^{R,P}	494	Invert
49-013-21088	West Pavillion 1-8-1B	1-8-1B	43.25619	-108.66944	6/19/1981	1981	1673.0^{G}	1,587	?	183.5	None^{B}	1404	Invert
49-013-21130	Tribal 21-9	21-9	43.25639	-108.65011	6/24/1981	1992	1642.9	1,617	1007.7	248.4	318	70	Invert
49-013-21129	Unit 12-3	12-3	43.26659	-108.63569	7/8/1981	---	1644.4^{G}	1,590	1043.3	185.9	?^{A}	?	Invert
49-013-21157	Runner Herfords 1	RH 1	43.23056	-108.65949	10/7/1981	1981	1632.8	1,221	1118.6	185.9	None^{B}	1035	Invert
49-013-21087	John K. Coolidge 1-4	1-4	43.26306	-108.64944	5/20/1982	---	1647.7	1,143	1072.3	200.6	<396	<195	Invert
49-013-21302	Tribal 14-24	14-24	43.21631	-108.4725	9/22/1982	1982	1575.8	2,698	1592.6	315.5	<579	<264	KCl polymer
49-013-21346	Fike Tribal A-1	A-1	43.29259	-108.64449	4/20/1983	---	1677.6	1,635	1010.1	184.7	515	330	Invert
49-013-21312	Ocean Lake Tribal 1-15	1-15	43.23789	-108.51091	4/24/1983	1990	1583.4	4,807	1143	304.8	<1189	<884	Invert
49-013-21421	Tribal B-1	B-1	43.29539	-108.65472	9/19/1984	1984	1671.5	1,674	?	181.4	?^{A}	?	Invert
49-013-21670	Pavillion Fee 33-11	33-11	43.24846	-108.6039	9/15/1993	---	1627.6	1,539	1051.6	190.8	<91	0	KCl polymer
49-013-21669	Pavillion Fee 12-11	12-11	43.25227	-108.61483	10/19/1993	---	1632.8	1,976	1005.8	191.1	268	77	KCl polymer
49-013-21676	Tribal Pavillion 11-10	11-10	43.25648	-108.6348	12/29/1993	---	1642.0	2,463	1044.5	190.5	792	602	KCl polymer
49-013-21696	Tribal Pavillion 42-10	42-10	43.254231	-108.620931	6/15/1994	---	1636.2	1,827	1009.5	190.8	789$^{R(3)}$	598	KCl polymer
49-013-21691	Tribal Pavillion 31-10	31-10	43.256365	-108.625138	6/25/1994	---	1637.4	1,820	1008.9	182.3	644	462	KCl polymer
49-013-21692	Tribal Pavillion 23-10	23-10	43.24889	-108.63068	7/15/1994	---	1647.7	1,829	1042.4	184.4	?^{T}	?	KCl polymer
49-013-21704	Tribal Pavillion 43-10	43-10	43.249234	-108.621267	9/21/1994	---	1639.2	1,815	1013.8	195.4	?^{A}	?	KCl polymer
49-013-21693	Tribal Pavillion 33-2	33-2	43.26208	-108.60522	11/8/1994	---	1631.6	1,676	1026.6	192.0	61	0	KCl polymer
49-013-21697	Tribal Pavillion 23-1	23-1	43.26396	-108.59019	11/11/1994	---	1651.7	1,617	1077.8	182.9	594	411	KCl polymer
49-013-21695	Tribal Pavillion 41-15	41-15	43.24277	-108.61865	11/23/1994	---	1631.0	1,989	1038.1	185.0	?^{N}	?	KCl polymer
49-013-21720	Tribal-Pavillion 43-6	43-6	43.26299	-108.5767	5/26/1995	---	1621.2	1,219	1108.3	128.0	?^{A}	?	KCl polymer
49-013-21806	Tribal Pavillion 23-11	23-11	43.25071	-108.60653	2/9/1998	---	1631.0	1,689	1013.2	167.0	<152	0	KCl polymer
49-013-21834	Tribal NP 31-11X	31-11X	43.2848	-108.57413	11/19/1998	---	1677.6	4,359	1158.2	705.9	?^{E}	?	KCl polymer
49-013-21904	Pavillion 13X-3	13X-3	43.26333	-108.63417	1/18/1999	1999	1630.7	1,842	1038.1	192.0	?^{T}	?	PHPA/LSND
49-013-21905	Pavillion Fee 42X-9	42X-9	43.25278	-108.63806	2/11/1999	---	1647.1	1,554	1055.8	185.9	518	332	LSND
49-013-21866	Pavillion Fee 41-11	41-11	43.25556	-108.6000	2/12/1999	----	1627.3	1,554	1032.7	169.2	76	0	LSND
49-013-21862	Tribal Pavillion 33-10	33-10	43.248612	-108.626454	5/6/1999	----	1667.3	1,820	1055.2	156.7	207	50	PHPA/LSND
49-013-21907	Tribal Pavillion 33-3	33-3	43.26306	-108.62556	5/25/1999	----	1642.0	1,190	1022.3	154.5	?^{T}	?	PHPA
49-013-21906	Tribal Pavillion 44-3	44-3	43.25944	-108.62111	6/29/1999	----	1638.9	1,832	1010.4	171.6	671^{R}	499	PHPA/LSND
49-013-21840	Tribal Pavillion 15-21X	15-21X	43.24055	-108.62952	7/2/1999	----	1688.3	4,919	1066.8	244.8	?^{T}	?	Invert
49-013-21968	Tribal Pavillion 32-10	32-10	43.253238	-108.630100	5/10/2000	----	1643.2	1,707	1005.8	190.8	610	419	LSND

API Number	Well Name	Abbreviation	Latitude	Longitude	Completion Date	Year Plugged & abandoned	Ground Elevation (m AMSL)	Total Depth (m)	Depth to Fort Union (m bgs)	Surface Casing (m bgs)	Top of Primary Cement (m bgs)	Mud Filled Interval Below Surface Casing (m)	Drilling Mud
49-013-22058	Pavillion Fee 13-11	13-11	43.24861	-108.61306	2/23/2001	----	1630.1	1,768	1005.2	186.5	<244	<58	PHPA
49-013-22057	Pavillion Fee 21-13	21-13	43.24083	-108.58861	2/23/2001	----	1620.0	1,067	?	134.7	? [N]	?	DeepDrill®
49-013-22068	Tribal Pavillion 43-2	43-2	43.26333	-108.59972	3/1/2001	----	1634.6	1,036	?	109.7	<107	0	Unknown[R]
49-013-22070	Tribal-Pavillion 13-2	13-2	43.26371	-108.6158	3/8/2001	----	1633.7	1,036	?	123.1	198	75	DeepDrill®
49-013-22101	Tribal-Pavillion 24-1	24-1	43.261667	-108.59056	3/23/2001	----	1637.7	1,036	?	125.0	122	0	LSND
49-013-22026	Tribal-Pavillion 32-1	32-1	43.26722	-108.58278	3/23/2001	----	1652.6	1,030	?	109.7	182.9	73	LSND
49-013-22072	Tribal Pavillion 34-2	34-2	43.26023	-108.60533	3/24/2001	----	1632.2	1,036	1022.9	118.0	15	0	LSND
49-013-22069	Tribal Pavillion 12-6	12-6	43.2675	-108.57555	3/29/2001	----	1620.0	1,097	1085.7	120.4	? [N]	?	DeepDrill
49-013-22027	Tribal Pavillion 44-1	44-1	43.26027	-108.58027	3/31/2001	---	1638.0	1,067	?	111.9	<122	<10	LSND
49-013-22099	Tribal Pavillion 14-10	14-10	43.245833	-108.635	4/13/2001	---	1640.7	1,067	974.75	110.3	442	332	DeepDrill®
49-013-22104	Pavillion Fee 13-15	13-15	43.23583	-108.63389	4/14/2001	2006	1632.5	1,113	?	132.9	? [N]	?	PHPA
49-013-22102	Pavillion Fee 12-11W	12-11W	43.25194	-108.615	5/3/2001	---	1632.5	991	?	131.1	594 [R]	463	LSND
49-013-22087	Pavillion Fee 34-3R	34-3R	43.26028	-108.62528	5/4/2001	---	1638.6	1,097	1015.0	110.3	668	558	PHPA
49-013-22059	Pavillion Fee 11-11	11-11	43.255122	-108.613706	5/17/2001	---	1632.2	1,782	1001.6	161.8	< 91[R]	0	PHPA
49-013-22061	Tribal Pavillion 12-5	12-5	43.2675	-108.55555	5/23/2001	---	1621.5	1,058	?	112.2	494	382	PHPA
49-013-22060	Pavillion Fee 13-12	13-12	43.250891	-108.593728	6/1/2001	---	1622.5	998	?	99.7	280	180	LSND
49-013-22103	Pavillion Fee 34-11	34-11	43.24514	-108.60531	6/13/2001	---	1628.5	1,024	?	161.5	? [A]	?	"gel"
49-013-22128	Tribal Pavillion 13-1	13-1	43.26433	-108.59553	6/28/2001	---	1652.3	1,071	?	163.1	? [N]	?	LSND
49-013-22105	Tribal Pavillion 11-12	11-12	43.25639	-108.59422	8/3/2001	---	1626.7	970	?	164.3	122	0	LSND
49-013-22125	Pavillion Fee 21-10	21-10	43.25625	-108.63078	8/10/2001	---	1641.0	1,807	1015	201.2	692	491	LSND
49-013-22145	Tribal Pavillion 43-1	43-1	43.26378	-108.58139	9/1/2001	---	1648.7	1,128	?	162.2	15	0	PHPA
49-013-22144	Tribal Pavillion 33-1	33-1	43.26381	-108.58536	9/6/2001	---	1646.8	1,059	?	163.1	15	0	LSND
49-013-22126	Tribal Pavillion 12-7	12-7	43.25265	-108.57613	9/8/2001	---	1621.8	1,021	?	164.0	? [N]	?	LSND
49-013-22188	Pavillion Fee 21-10W	21-10W	43.25625	-108.63039	9/15/2001	---	1640.4	1,341	1011.9	189.0	442	253	LSND
49-013-22186	Pavillion Fee 23-12	23-12	43.250699	-108.589188	9/19/2001	---	1621.5	994	?	162.8	15	0	LSND
49-013-22147	Tribal Pavillion 44-2	44-2	43.26011	-108.60217	9/22/2001	---	1634.3	1,250	1021.1	162.8	? [A]	?	?
49-013-22172	Pavillion Fee 31-9	31-9	43.25686	-108.64486	9/28/2001	---	1645.6	1,050	?	162.8	61	0	LSND
49-013-22149	Tribal Pavillion 34-10	34-10	43.24658	-108.62526	10/6/2001	---	1646.5	1,747	1046.4	197.5	<188	0	LSND
49-013-22146	Tribal-Pavillion 34-1	34-1	43.26083	-108.58639	10/13/2001	---	1639.8	1,020	?	162.8	? [A]	?	LSND
49-013-22150	Tribal Pavillion 21-12	21-12	43.25639	-108.59114	10/20/2001	---	1629.2	1,128	?	107.3	159	52	LSND
49-013-22141	Tribal Pavillion 12-10	12-10	43.25167	-108.63556	11/7/2001	---	1645.0	1,496	?	189.6	31	0	LSND
49-013-22181	Tribal Pavillion 12-1	12-1	43.26778	-108.59169	11/10/2001	---	1642.0	1,128	?	162.8	73	0	LSND
49-013-22191	Tribal Pavillion 42-3	42-3	43.26778	-108.61922	11/16/2001	---	1641.0	1,227	1035.4	162.8	< 61	0	LSND
49-013-22180	Tribal-Pavillion 22-1	22-1	43.26725	-108.59011	11/21/2001	---	1657.2	1,128	?	162.5	46	0	LSND
49-013-22195	Tribal Pavillion 33-10W	33-10W	43.248702	-108.626805	12/6/2001	---	1668.2	1,545	1054.6	160.9	204	43	LSND
49-013-22153	Tribal Pavillion 41-3	41-3	43.27056	-108.62056	12/7/2001	---	1643.8	1,228	1037.2	157.6	? [A]	?	LSND
49-013-22215	Pavillion Fee 22-11	22-11	43.25283	-108.61128	12/15/2001	---	1632.2	972	?	189.0	? [A]	?	LSND
49-013-22200	Pavillion Fee 43-11	43-11	43.25089	-108.60044	12/22/2001	---	1627.0	1,219	1026.3	162.5	<122	0	LSND
49-013-22212	Pavillion Fee 11-3	11-3	43.27083	-108.63369	1/9/2002	---	1647.7	1,216	1032.4	160.9	? [N]	?	LSND
49-013-22198	Pavillion Fee 41-10	41-10	43.255851	-108.620913	1/23/2002	---	1637.4	969	?	162.8	165	2	LSND
49-013-22214	Pavillion Fee 13-12W	13-12W	43.2485	-108.59681	1/26/2002	---	1624.3	1,227	1044.9	159.7	0	0	PHPA
49-013-22229	Pavillion Fee 24-3B	24-3B	43.25947	-108.63089	2/8/2002	---	1641.3	1,731	1012.9	200.9	<30	0	LSND
49-013-22220	Pavillion Fee 11-11B	11-11B	43.25697	-108.61594	2/16/2002	---	1635.3	1,457	1004.3	170.7	<152	0	LSND
49-013-22106	Pavillion Fee 31-11	31-11	43.25703	-108.60528	2/22/2002	---	1629.5	1,207	1019.6	165.8	<15	0	LSND
49-013-22207	Pavillion Fee 23-3	23-3	43.26411	-108.62944	2/27/2002	---	1644.4	1,890	1022	189.0	? [A]	?	?

API Number	Well Name	Abbreviation	Latitude	Longitude	Completion Date	Year Plugged & abandoned	Ground Elevation (m AMSL)	Total Depth (m)	Depth to Fort Union (m bgs)	Surface Casing (m bgs)	Top of Primary Cement (m bgs)	Mud Filled Interval Below Surface Casing (m)	Drilling Mud
49-013-22223	Pavillion Fee 32-11	32-11	43.25356	-108.60664	3/2/2002	---	1630.7	1,219	1016.8	175.0	0	0	LSND
49-013-22199	Pavillion Fee 44-11	44-11	43.24513	-108.60059	3/6/2002	---	1627.0	1,241	1036.3	162.2	?[A]	?	LSND
49-013-22228	Pavillion Fee 42-9W	42-9W	43.25308	-108.64158	3/21/2002	---	1642.9	1,042	?	161.8	0	0	LSND
49-013-22227	Pavillion Fee 32-9W	32-9W	43.25408	-108.64472	3/22/2002	---	1645.6	1,055	?	162.2	0	0	LSND
49-013-22224	Tribal Pavillion 32-10B	32-10B	43.25328	-108.62539	3/28/2002	---	1638.0	1,783	1012.9	189.6	55	0	LSND
49-013-22240	Pavillion Fee 13-11B	13-11B	43.24961	-108.61672	4/9/2002	---	1633.7	1,725	1016.2	188.1	625[R(4)]	437	LSND
49-013-22219	Pavillion Fee 14-3W	14-3W	43.26072	-108.63575	4/13/2002	---	1644.7	1,737	1027.5	189.0	0	0	LSND
49-013-22182	Tribal-Pavillion 12-2	12-2	43.26694	-108.61506	12/1/2002	---	1634.9	1,128	1036.3	159.1	30.5	0	LSND
49-013-22217	Tribal-Pavillion 23-10W	23-10W	43.24886	-108.63153	12/19/2002	---	1648.4	1,399	1041.8	162.8	0	0	LSND
49-013-22418	Tribal Pavillion 23-10C	23-10C	43.24789	-108.62947	10/13/2004	---	1656.1	1,747	?	175.6	?	?	LSND
49-013-22270	Pavillion Fee 34-3B	34-3B	43.26033	-108.62783	10/24/2004	---	1640.1	1,829	1005.8	196.6	838[R]	641	LSND
49-013-22236	Tribal Pavillion 24-2	24-2	43.259882	-108.610983	11/4/2004	---	1636.2	1,202	1020.8	171.3	213[R]	42	LSND
49-013-22417	Tribal Pavillion 23-10B	23-10B	43.25047	-108.63122	11/5/2004	---	1649.0	1,721	1036.3	195.4	299	104	LSND
49-013-22274	Tribal Pavillion 33-10B	33-10B	43.249535	-108.624267	12/14/2004	---	1638.0	1,710	1024.1	194.8	61	0	LSND
49-013-22272	Pavillion Fee 12-11B	12-11B	43.254237	-108.615986	1/15/2005	---	1634.3	1,177	1001.9	167.9	311[R]	143	LSND
49-013-22420	Tribal Pavillion 43-10B	43-10B	43.247613	-108.620928	1/20/2005	---	1657.8	1,756	1036.3	193.9	357[R,P]	163	LSND
49-013-22222	Tribal Pavillion 24-11	24-11	43.24517	-108.61017	1/20/2005	---	1630.7	1,197	1028.7	160.9	177	16	LSND
49-013-22268	Pavillion Fee 31-10B	31-10B	43.25494	-108.62822	1/23/2005	---	1639.2	1,693	1011.3	192.0	411[R]	219	LSND
49-013-22313	Pavillion Fee 33-11B	33-11B	43.25061	-108.60636	1/24/2005	---	1629.8	1,212	?	155.8	146	0	"water based"
49-013-22599	Pavillion Fee 44-11B	44-11B	43.24686	-108.60303	1/26/2005	---	1627.6	1,203	1033.3	193.5	183	0	LSND
49-013-22216	Tribal Pavillion 21-14	21-14	43.24125	-108.60981	1/28/2005	---	1632.2	1,707	1050	192.0	?[T]	?	LSND
49-013-22243	Pavillion Fee 13-10	13-10	43.24911	-108.63539	2/3/2005	---	1642.6	1,739	1045.5	193.2	?[N]	?	LSND
49-013-22269	Pavillion Fee 21-10B	21-10B	43.25481	-108.63272	2/3/2005	---	1640.4	1,715	1013.2	193.2	1265[R]	1072	"water based"
49-013-22600	Pavillion Fee 43-11B	43-11B	43.24806	-108.60033	2/11/2005	---	1626.1	1,203	1031.7	192.9	0	0	"water based"
49-013-22324	Tribal Pavillion 42-10B	42-10B	43.25219	-108.62019	2/16/2005	---	1635.6	1,708	1009.2	189.3	0	0	LSND
49-013-22271	Pavillion Fee 22-11B	22-11B	43.25147	-108.61264	2/16/2005	---	1632.5	1,372	1010.7	192.3	0	0	"water mud"
49-013-22419	Tribal Pavillion 32-10C	32-10C	43.252211	-108.627491	2/18/2005	---	1640.1	1,225	?	190.8	31	0	LSND
49-013-22314	Pavillion Fee 22-11C	22-11C	43.25431	-108.60886	2/23/2005	---	1631.6	1,173	955.55	193.5	?[N]	?	LSND
49-013-22634	Pavillion Fee 44-4	44-4	43.25944	-108.63994	3/15/2005	---	1644.1	1,737	?	186.2	SBL		LSND
41-013-22255	Tribal Pavillion 12-12	12-12	43.253	-108.59683	3/17/2005	---	1625.8	1,205	1049.1	193.5	290[R]	97	"water based"
49-013-22617	Tribal Pavillion 33-2C	33-2C	43.26319	-108.60839	3/22/2005	---	1632.2	1,131	1027.2	194.8	15	0	LSND/PHPA
49-013-22627	Tribal Pavillion 13-2B	13-2B	43.26333	-108.61317	3/29/2005	---	1633.7	1,210	1026	196.6	15	0	?
49-013-22633	Pavillion Fee 43-4	43-4	43.262618	-108.640212	4/2/2005	---	1645.6	1,446	1035.1	182.9	15	0	LSND
49-013-22625	Tribal Pavillion 33-2B	33-2B	43.26322	-108.60333	4/5/2005	---	1633.1	1,129	1034.8	196.6	15	0	LSND
49-013-22623	Pavillion Fee 14-3B	14-3B	43.25944	-108.63425	4/5/2005	---	1642.6	1,199	1028.7	189.0	15	0	DeepDrill®
49-013-22601	Pavillion Fee 41-11B	41-11B	43.25703	-108.6025	4/14/2005	---	1628.5	1,189	1017.1	196.0	274	78	?
49-013-22635	Pavillion Fee 42-4B	42-4B	43.26764	-108.63994	4/16/2005	---	1649.3	1,209	1046.1	196.6	198	1	LSND
49-013-22586	Tribal Pavillion 21-11B	21-11B	43.256953	-108.610928	4/19/2005	---	1632.2	1,181	988.47	195.7	15	0	LSND
49-013-22246	Pavillion Fee 13-3W	13-3W	43.262919	-108.636420	4/23/2005	---	1645.6	1,403	1026	185.3	198	13	LSND
49-013-22624	Pavillion Fee 41-10B	41-10B	43.256943	-108.620175	5/7/2005	---	1637.1	1,171	996.39	195.1	152	0	LSND
49-013-22642	NW Pavillion Fee 34-28	34-28	43.28969	-108.64469	5/24/2005	---	1666.6	1,721	1018.9	196.0	?[N]	?	DeepDrill®
49-013-22259	Tribal Pavillion 32-3	32-3	43.26658	-108.62586	6/12/2005	---	1643.5	1,664	1013.8	196.3	?[A]	?	LSND
49-013-22171	Pavillion Fee 43-9	43-9	43.25081	-108.63997	6/16/2005	---	1642.0	1,728	1055.2	196.0	31	0	DeepDrill®
49-013-22258	Tribal Pavillion 22-3	22-3	43.26844	-108.63169	7/16/2005	---	1645.9	1,676	1029.6	196.0	<183	0	"water based"
49-013-22721	Tribal Pavillion 44-3C	44-3C	43.26136	-108.62278	7/19/2005	---	1640.7	1,190	1004.9	196.0	46	0	?

API Number	Well Name	Abbreviation	Latitude	Longitude	Completion Date	Year Plugged & abandoned	Ground Elevation (m AMSL)	Total Depth (m)	Depth to Fort Union (m bgs)	Surface Casing (m bgs)	Top of Primary Cement (m bgs)	Mud Filled Interval Below Surface Casing (m)	Drilling Mud
49-013-22245	Tribal Pavillion 32-2	32-2	43.26949	-108.6039	3/30/2006	---	1640.1	1,609	1052.8	195.1	0	0	"Gel-Chem"
49-013-22824	Pavillion Fee 33-12	33-12	43.24928	-108.58614	4/1/2006	---	1619.1	1,682	1060.7	193.9	61	0	"Gel-Chem"
49-013-22819	Haymaker 14-21	14-21	43.24208	-108.49453	5/16/2006	---	1606.0	3,597	1349.0	766.3	? [E]	?	KCl polymer
49-013-22825	Pavillion Fee 22-4	22-4	43.26606	-108.65239	4/3/2007	---	1651.4	1,674	1074.7	158.5	61	0	PHPA
49-013-22100	Tribal Pavillion 42-15	42-15	43.23981	-108.62144	4/12/2007	---	1634.6	1,659	1033	157.6	? [A]	?	PHPA
49-013-23068	Leonhardt 41-26	41-26	43.1249	-108.28517	6/5/2007	2007	1557.2	2,286	1207	202.7	None [B]	2083	Water based

Coordinates for Tribal Pavillion 32-2 incorrect in well file –approximate coordinates provided.

Abbreviations
AMSL – Absolute mean sea level
bgs – Below ground surface
? – Unknown
PHPA - partially hydrolized polyacrylamides
LSND - low solids non-dispersed drilling mud
DeepDrill® is a product of Newpark Drilling Fluids and is described as a buffered blend of polyhydroxyl alcohols. No MSDS on this product was provided to EPA.

Superscripts

A - Cement bond log (CBL) conducted at completion but not available
B - No apparent use of production casing in borehole
E - Either cement bond log not conducted at completion or not available
G - Ground elevation estimated from coordinates using "GPS Visualizer" located at: http://www.gpsvisualizer.com/elevation.
I – Invert mud below intermediate casing at 1236 m bgs at 33X-10
N - Well completion report indicates cement bond or temperature log not conducted at completion
P - Parted casing, leak in casing, or casing failure
R - Remedial cement squeeze(s) following primary cement. Number of CBLs in parenthesis
T - Top of cement difficult to discern – high amplitude readings in cement bond log

Table SI C2. Description of stimulation stages in the Pavillion Field. Information obtained from well completion reports using API search number

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (Mpa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
MHR 1		MV													P&A after completion in 1953. "Water sands" at 5780'-5810', 7145'-7250', 7970'-8040', 9000'-9100', Filled with "heavy mud" from 2,141'-11,000'. Cement plug from 2017'-2141' Intermediate casing cut at 1700' and pulled. No production or stimulation.	Yes
14-12	634.6	WR	12/20/1999	8.76	9.46	9	10.93	8.36		X		15,150 2		1,134	"Pumped 25# linear gel w/75 % CO2, 157 bbls fluid, 85 tons CO2"	No
	941.8	WR	12/11/1999	15.93						X		314 sxs			"137 bbls 75% CO2 foam"	
	1004.0	WR	11/3/1964		10.34	10.69		4.83		X		5,103			"Frac treated Wind River interval 3294'-3370' and Fort Union interval 3782'-3789'…w/25000 gals 9.6#/gal salt wtr…Total load 947 bbls wtr...well flowed diesel and load wtr" "Lost 150 bbls KCl fluid"	
	1152.8	FU	4/17/1980	6.89						X					"Acidz w/2500 gal 12% i & Tylene...salt water...total load 947 bbls wtr...Flowing at rate…16 bbls salt wtr and diesel oil/day." Sundry notice dated 2/15/1980 for workover using "a. 1000 gal 15% HCl containing 2 gals A-200 inhibitor, 2 gals M38W surfactant, 1 gal J-237 diverter, and 35 lbs L-41 iron sequestering agent b. 5500 gals 12% HCl, 3% HF mud acid containing 10% U-66 mutual solvent, 22 gals A-200 inhibitor, 11 gals surfactant, 195 lbs L-41 iron sequestering agent. c. 2500 gals 3% HCl with A-200 inhibitor, M38 surfactant, and 12.5 gals L-53 clay stabilizer. Displace with 17.5 bbls 3% ammonium chloride water containing surfactant and clay stabilizer."	
	1618.5	FU	8/5/1960							X					"250 gallons of "breakdown acid" followed by cement squeeze.	
	1630.1	FU	8/5/1960							X					"250 gal breakdown acid" followed by cement squeeze	
	1875.7	FU	8/3/1960							X					"250 gal breakdown acid" followed by cement squeeze	
23-7		L													P&A after completion in 1961.Well history missing from well completion report.	No
W 1		MT													P&A after completion in 1961. No apparent production well casing. No stimulation or production.	No
23-2	501.7	WR	6/16/2001	9.38	7.58	30				X		13,605	0	130	"70Q CO2 foam"	No
	536.4	WR	6/16/2001	17.93	12.07	35				X		19,210			"70Q CO2 foam"	
	679.1	WR	6/15/2001		9.65	25				X		10,725			"70Q CO2 foam"	
	720.5	WR	6/15/2001		12.76	25				X		21,955			"70Q CO2 foam"	
	893.1	WR	2/1/1965							X					"Frac all zones"	
	1035.4	FU	2/1/1965							X					"Frac all zones"	
22-35		FU													P&A after completion in 1963. No apparent production well casing. Well history missing from well completion report. No record of production or stimulation.	No
GOL 1		FU													Completed in 1963. Perforated in three intervals in WR Formation. Put into production on 6/11/1963. P&A in 1974. No information on stimulation.	No
14-1	322.5	WR	1/5/2000		4.76	6.96				X		217 sks	0	2,735	"Totals pumped 54 tons CO2…4360 gals w/methanol."	No
	618.4	WR	4/1/1993							X					"1500 gal 15% HCL"	
	713.8	WR	4/1/1993							X					"1500 gal 15% HCL"	
	925.4	WR	10/16/1964	22.75	16.55	43	17.24	10.34		X					"Injected 12,000 gallons #2 diesel into intervals 3036'-3045' and 3744'-3780'. In sundry notice dated 3/25/1993 plan to "plug back water bearing perforation in the Fort Union at 3744-3780."	
21-8		WR													Perforated in WR Formation. Completed in 1963 as a shut-in well and P&A unknown time later. Well history and completion information missing.	No
21-5	352.0	WR	12/8/1999							X			0	898	Recompletion in 1999. "HES 70Q foam, 4 gal/M HgClean, 4% KCl" on 12/8/1999. Numerous perforated and squeezed intervals. No documented production or stimulation prior to recompletion.	No
U 13-13		FU											2	1,130	Production from Fort Union Formation. Information on completion and possible stimulation missing from well completion report.	No

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (Mpa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
14-6		WR											0	27	Production from Wind River Formation. Information on completion and possible stimulation missing from well completion report.	No
32-4		FU													P&A after completion in 1963. Information on well history missing from completion report. No apparent production well casing. No stimulation or production.	No
24-14		FU											2	1,834	Production from base of Wind River Formation. Five perforated intervals between 3443'-3515' without stimulation.	No
44-20		FU													P&A after completion in 1964. No apparent production well casing or production. Drilling report missing from well completion report.	No
23X-24		FU													P&A after completion in 1964. No apparent production well casing or production. Cement plugs at surface, 522'-675', 2035'-2200', and 3765'-3930',	No
44-17		FU													P&A after completion in 1964. No apparent production well casing or production.	No
34-33		FU													Perforated at 2566'-2588' in WR Formation. No information on stimulation or production. Well history missing from well completion report. P&A date unknown	No
33X-10	986.3	WR	2/22/1965	21.36		16.5		6.89		X	5,897	0		0	In 1964, acidized in Frontier Formation with "15,000 gals MCA." In 1964, "sptd 500 gals 15% HCl on perfs [in WR Formation] & broke formation down w/1400 psi TP (600 psi CP)…total load 532 bbls. "Frac treated Wind River pers…15,000 gals 9.6#/gal salt water containing fluid loss additives…Total load 933 bbls" Completed in 1964. P&A in 1983. Drilled to Madison Formation.	Yes
24X-3	1359.4	FU	4/28/1966			1.0 8	27			X			2	9,653	"Treated…w/1000 gal P-12 solvent (Dow) containing 10 gal free-flo 'C'"	No
14-11		WR											2	1,426	Producing from Wind River Formation. Perforations from 3192'-3864'. Well completion report is not available.	No
13-13	1018.0	WR	9/7/1965	16.55		23.0	24.82	19.31		X	2,268				"Breakdown with…salt water…spearhead frac with 500 gal. 15% HCl. Frac with … 5000 gal 4% salt water."	
	1099.7	FU	9/6/1965	14.48		28.5		14.48		X	5,443				"Breakdown with 750 gal salt water…Inj 500 gal. 15% HCl. Frac with…12,000 gal 4% salt water."	
	1099.7	FU	11/6/1965			21.6	28.96	27.58		X	5,443				"Diesel frac with 24000 gal diesel."	
32-9		FU													P&A after completion in 1968. No apparent production well casing or production. Cemented intervals 567-667', 1200-1300', 3200-3300' during P&A.	Yes
WEL 47	89.3	F	6/14/1971												Drilled to Mowry Formation. Acidized in Frontier formation with 50,000 gal 7-1/2% HCl and 1000 gal KCl. 1979. P&A in 1981.	Yes
41X-10	551.4	WR	2/7/1973			19.31		13.79		X					Invert mud contained up to 78% oil while drilling. "Frac treated...as follows...9# KCl wtr containing 5# J-133/1000 gal...2500 gal 15% HCl containing 5# J-133/1000 gal...9120 gal 9# KCl wtr containing 40# J-133, 20# J-110 and 1 gal F-63/1000 gal, 1# J-134 and 400 scf/bbl nitrogen...1460 gal 9# KCl wtr containing 560# J-133, 300# J-110, 15 gal F-63, 2 gal J-34 and 139,000 scf nitrogen...flushed w/9# KCl wtr containing 5# J-133/1000 gal…Well flowed back approx. 600 BLW since opened to pit…considerable amt of wtr." Completion report indicates that 2675 bbls of water flowed to pit between 2/7/1975 – 3/7/1975. On 3/9/1975, "A total of 145 bbls 9.23/gal KCL water was used to keep well under control…flowed control water to pit. Flowed 142 bbls in 10 hrs." Between 3/12/1975-3/26/1975, 745 bbls of water flowed from well. In correspondence dated 5/27/1980 [not in well file - obtained from landowner], 41X-10 recommended for plugging and abandonment because of "problems with water production and casing failure." P&A in 1981 with cement plugs (40 sxs each) at 2400', 2900' and 3456'.	Yes

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (MPa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
	1232.6	FU	2/8/1979			6.0	44.82	22.75		X		47,174			While perforating FU Formation "Flowed well to pits continuously." "Controlled well w/4% KCl wtr w/clay stabilizer & surfactant. Lost 80 bbls to form while doing so…acdz'd gross perf 4044-4450 w/4000 gals 15% HCl acid…Opened well to pit & cont'd to flw to pit overnight to cleanup." "Foam frac treated with 90,000 gals to qualify foam, 1,950,000 SCF nitrogen & 645 bbls gelled KCl wtr for sd carrying agent. Total load to rec 645 bls." ISIP for acid stimulation = 4.14 MPa. Updated well schematic in WOGCC (2014).	
41X-2		WR	11/28/1973												17 perforations from 1554'-4398' with diesel oil to control well. No documented stimulation or gas production	No
31X-3	395.6	WR	8/30/2001							X			0	1,215	Completed in Dec 1973 with 27 holes from 1665'-4988' and 8 holes 3154'-3161' – no apparent stimulation. Stimulated in Aug 2001, "Frac 1298-1309"	No
42X-11		WR											0	222	30 perforations from 2014' -4741' and 3 perforated intervals from 3773' and 3793' during initial completion in 1974. No documented stimulation fluids. 20 perforated intervals added during recompletion in 2001. No documented stimulation.	No
42X-12	1149.7	FU	1/19/1974							X			0	295	"400 gal 15% HCl"	No
31X-14		WR											2	7,691	Producing from Wind River Formation. Perforations in Wind River and Fort Union Formations during initial completion in 1974 - no apparent stimulation.	No
CCD		MV													P&A after completion in 1974. No apparent production well casing. No stimulation or production. Water at 2715'. Converted to water well.	No
TR1-22	961.6	WR	2/7/1980							X			0	5,281	In Sundry Notice dated 2/7/1980, " Proposed procedure…Acidize well using a 3 stage acid program: a) 500 gal 15% HCl b) 2000 gal RMa c 500 gal 7.5% HCl. Note: all acid should contain 400 cc N2/Bbl acid, 10% mutual solvent and a clay stabilizer...Frac well down tubing"	No
1-21		FU													"Lost 80 bbls mud to formation, probably in fractured zone 2738-43 [at 2749'-2790'] lost additional 60 bbls mud." P&A after completion in 1976. No apparent production well casing. No stimulation or production. Cement plugs at 550'-700', 3500'-3650' and 3830' – 3965'.	No
TP 1		WR											0	5,607	7 perforated intervals between 3406-3572. No record of stimulation.	No
1-31		WR													Perforations at 2900' and 3580'. Well completion report not available.	No
TU 1		WR											0	220	Perforated from 3460'-3537'. No record of stimulation.	No
4-8	630.9	WR	2/12/2005	13.10	26.05	18.0	39.38			X		10,160	365	63,110	"Frac slickwater, 104 bbl s" Updated well schematic in WOGCC (2014).	Yes
	814.1	WR	2/8/2005	18.27			38.24	9.45		X		95,254			"Frac: slickwater...121-bbls 6% KCl, 28.5 tons of CO2"	
	1484.4	FU	3/26/1977							X		61,235			"500 gal 15% BDA frac w/102,000 gallons of gel water…300 scfpb nitrogen"	
34-13		FU											0	290	Perforations from 2664-2676. Information on well completion missing.	No
T24-11															P&A after completion in 1978. No apparent production well casing. No stimulation or production.	No
24-4		WR													P&A after completion in 1978. No apparent production well casing. No stimulation or production.	No
44-15	1285.3	FU	5/3/1976	22.06	9.65			4.83		X			2	1,348	"1500 gal 15% HCl…dis pl'd w/28 bbls 2% KCl wtr."	No
	1367.3	FU	4/28/1978	24.13	15.17		24.13	6.21		X					"Acdz'd w/1500 gals 15% HCl…Displ'd w/32 bls 2% HCl."	
	1530.1	FU	4/25/1978	15.86	13.79			10.34		X					"Spt'd 750 gals 15% HCl…Displ'd acid w/29 bbls 2% KCl."	
	1530.4	FU	4/24/1978	20.68	13.79			6.55		X					"Pump 1500 gal 15% HCl…displacing acid w/40 bbls KCl."	
	1530.4	FU	4/21/1978	33.09	10.34	4.0		6.55		X					"Pmp'd 500 gals 7-1/2% HCl…Displaced acid w/38 bbls 2% KCl."	
21-11	958.3	BWR	3/12/1979	13.79	6.89			4.83		X		5,897	0	335	Acidize w/850 gals 7 1/2% HCl w/2 als C-17, 2 gals J-501 II, 8 gals J-38 & 25# citric acid. Frac w/15000 gals YE4P5D fluid…Pump 5000 gal 3% HCl acid, displace w/2% HCl water." 13 perforated intervals from 1681-2750 in April 2001 without apparent stimulation.	No
	1213.7	FU	2/23/1979		12.41	4.5	12.41	5.52		X					"Pump 3150 gals 7 1/2% HCl…6 gals M38W, 6 gals A200, 13 gals L-53 & 15 gals U-40."	

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	1471.6	FU	2/21/1979		13.79	4.5	22.06	6.89		X					"Breakdown w/1100 gals 7 1/2% HCl w/2 gal M38W, 2 gal A200, 4 gal L-53 & 25/L-41. Displace w/9 bbls L-53 water foll'd 9 bbls fresh water."	
12-13	578.5	WR	5/16/2001							X		10,259	0	18	"CT [coiled tube] frac 256 bbls, 177 mcf N2". Updated well schematic in WOGCC (2014).	Yes
	1032.7	WR	2/5/1981							X		26,762			"Acidize w/4000 gals 7 1/2 %...Frac BWR…versa gel"	
	1134.2	FU	3/22/1979	24.82	11.72					X		91			"Frac [with] 4 bbls L53+15 bbls L53 wtr+6bbls acid." "Lost thousands of bbls KCl to Basal wind river."	
	1296.0	FU	3/19/1979							X					"Acidize w/6000 gals wtr." 4252-4580 "WET"	
41-9	560.5	WR	10/1/2004							X		5,443	2	15,593	"74 bbls 6% KCl, 16.3 tons CO2...Frac down casi ng"	No
	634.0	WR	10/1/2004							X		5,443			"78 bbls 6% KCl, 16.3 tons CO2...Frac down casing"	
	688.2	WR	10/1/2004							X		5,443			"82 bbls 6% KCl, 16.3 tons CO2...Frac down casing"	
	788.2	WR	10/1/2004							X		5,443			"87 bbls 6% KCl, 16.3 tons CO2"	
	826.6	WR	10/1/2004							X		6,804			"100 bbls 6% KCl, 20.4 tons CO2"	
	876.0	WR	10/1/2004							X		6,804			"103 bbls 6% KCl, 20.4 tons CO2"	
	1129.6	FU	10/1/2004			35.0	16.87			X		8,165			"128 bbls 6% KCl, 24.4 tons CO2, 18,843 gal 70Q CO2 WF125...Frac down casing." In proposed fracturing schedule "Pumping schedule to achieve a propped fracture half-length (Xf) of 82.9 ft with an average conductivity of (Kfw) of 3383 md.ft…gel conc 7.5 lb/mgal"	
	1163.1	FU	10/1/2004		17.39	35.0	17.51			X		27,216			From stimulation report: "281 bbls 6% KCl, 81.4 tons CO2, 33,656 gal 70Q CO2 WF125...Frac down casing". In proposed fracturing schedule "Pumping schedule to achieve a propped fracture half-length (Xf) of 197.6 ft with an average conductivity of (Kfw) of 5366 md.ft...Gel conc 7.5 lb/mgal." Composition of WF125 from stimulation report: 2.00 gal/mgal F103 surfactant, 3.00 gal/mgal F104 foamer, 15.00 lb/mgal J218 breaker, 1.0 gal/mgal J318 liquid breaker aid, 5.63 gal/mgal B142 guar polymer slurry, 2.00 gal/mgal L55 clay stabilizer.	
	1472.2	FU	8/1/1979	15.17	11.03	4.0		4.14		X					"Lost approx. 50 bbls mud in 24 hrs." [invert mud while drilling] "At'd gross Ft. Union perfs 4830-5097 with 4000 gal 7.5% HCl containing 2 gals A-200, 2 gals M38W, 4 gals L-53 and 35% L-31 per 1000 gal acid. Press csing to 1200 psi with invert oil. Pumped 1000 gal acid…spaced…ball sealers in next 2500 gal acid. Followed with 500 gal acid without ball sealers. Flushed with 20 bbls 2% KCl water containing 6 gal L-53 clay stabilizer." "A total of 65 bbls invert oil has been pmp'd into well" [to control well].	
TU 2	1069.5	WR	8/24/1979							X					"2500 gal 7-1/2% HCl" Cement squeeze after stimulation	No
	1074.4	WR	8/24/1979							X					"500 gal 15% HCl"	
22-10	607.8	WR	12/14/2004	13.00			18.58	8.14		X		6,554	2	1,363	"89 bbls of clean fluid, 2 2 ton CO2"	Yes
	660.8	WR	12/14/2004	22.34			22.37	8.45		X		9,085			"129 bbls of clean fluid…29 tons of CO2"	
	734.3	WR	12/14/2004	29.65			29.65	8.95		X		6,559			"270 bbls of clean fluid…17 tons CO2"	
	937.6	WR	12/14/2004	28.96			28.96	9.51		X		10,841			"165 bbls of clean fluid…27 ton CO2"	
	994.3	WR	12/14/2004				11.76	0.69		X		10,886			"Frac: pump 92 bbls of 6% KCl…didn't see a break…clean fluid 242 bbl…34 tons CO2"	
	997.9	FU	10/6/1979	7.58		4.0		1.17		X		0			"A.T. perfs 3274-94 w/1000 gals 15% HCl & 48 frac balls…acid containing 2 gals inhibitor, 2 gals surfactant, 4 gals clay stabilizer & 3-5# iron sequestration per 1000 gals acid. Formation broke ...Flushed 20 bbls of clay stabilizer water."	
	1384.1	FU	12/11/2004	31.21			46.68	32.08		X		7,824			"Frac 10 bbls to catch pressure…clean fluid 119 bbls…19 ton CO2"	
	1396.3	FU	12/9/2004	31.90			49.29	1.94		X		24,176			"260 bbl clean fluid…55 tons CO2"	
	1468.8	FU	9/12/1979					5.17		X					"Pmp'd 57 bbls 9#/gal KCl w/.5 gal per bbl brine saver, .2 surfactant & .5 clay stablizer…pmp'd 5 bbls KCl into formation…pmp'd 40 bbls 9#/gal KCl @ 3 BPM 600# into formation…acidized …w/3400 gal 15% HCl…Flushed w/25 bbls of fresh water containing clay stablizer.	
	1530.1	FU	9/12/1979							X					"Acid treat w/3400 gal 15% HCl"	

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G 1		FU													P&A after completion in 1979. No apparent production well casing. No stimulation or production.	No
21-15	799.2	WR	9/1/1982							X			0	24	"1000 gallons of 15% HCl". Completion record reviewed by WOGCC in letter to BLM dated 8/14/2012 concerning of 1,000 gallons of a 15% HCl solution in "compromised" casing between 735 to 1,105 feet below ground surface.	Yes
	1014.7	WR	11/21/1979							X		55,792			"Frac treat B.W.R….w/60,000 gals DOWELLS Y-F4 PSD frac fluid"	
	1071.4	WR	11/19/1979	11.03	10.34	7.0		2.07		X					"Pmp'd 3450 gals 15% HCl containing 4 gals A-200 inhibitor, 2 gals M-38 W surfactant 4 gals L-53 clay stabilizer 35# L-42 iron sequestration agent/1000 gals of acid"	
	1071.4	FU	11/12/1979		13.79	7.0	13.79			X					"A.T…w/2500 gal 15% HCl containing 2 gals A-200, 2 gals M-38 W, 4 gals L-53, 35# L-41 per 1000 gals acid…Displaced acid w/17 bbls fresh wtr containing L-53 clay stabilizer."	
	1084.8	FU	9/1/1982							X					"1700 gallons 15% HCl."	
	1187.5	FU	11/2/1979		16.72	6.5		3.45		X					"Pmp'd 2500 gals 15% HCl…Acid contained 2 gals inhibitor, 2 gals surfactant, 4 gals clay stabilizer, 35 lbs S-41 iron sequestration agent/1000 gals…Dispaced acid w/19 bbls fresh wtr containing 4 gals clay stabilizer"	
44-10	820.2	WR	10/14/2004	21.84	8.41	14.4		3.68	14.70	X		9,072 2		1,751	From WOGCC (2014), this interval was fracture treated with 150 barrels of CO2 assisted gelled water. Updated well schematic in WOGCC (2014)	No
	869.9		10/14/2004	22.64	8.32	14.6			19.91	X		8,115			"Frac: Gel total load 218 bbls" From WOGCC (2014), this interval was fractured treated with 218 barrels of CO2 assisted gelled water.	
	984.5	WR	12/17/1979			11.72				X					"Acidize: 3000 gal 15% HCl"	
	1094.8	FU	10/1/2004	31.28				10.68		X		8,165			"Break formation with 6% KCl…total fluid pumped 134 bbls" From WOGCC (2014), " In October 2004 additional Fort Union Sands were selectively perforated between 3,592' and 4,925', and fracture treated with a total of 1,303 barrels of CO2 assisted gelled water."	
	1119.8	FU	10/5/2004					3.12		X		9,979			"197 bbls clean fluidand 20 tons of CO2 See note above on gelled water.	
	1147.6	FU	10/1/2004					8.32	12.89	X		27,216			"97 tons CO2 and 276 bbls clean fluid". See note above on gelled water.	
	1400.6	FU	9/24/2004							X		22,453			"KCl prepad…pump 70 quality CO2 foam frac…88 tons CO2 and 11042 gal clean fluid." See note above on gelled water.	
	1452.1	FU	9/21/2004			46.51		10.51		X		7,257			"Frac: 164 bbl 6% KCl, 150 bbl CO2" See note above on gelled water.	
	1482.5	FU	9/17/2004	37.11	20.08	20.6		4.01		X		20,412			"269 bbls clean fluid and 440 bbls CO2" See note above on gelled water.	
	1531.9	FU	12/17/1979			19.99				X					"Acidize: 1500 gal 15% HCl" During cementing on 6/27/1979, "Pmp'd 30 bbls diesel ahead mixed w/5 gals surfactant…Lost returns last 40 bbls."	
22-12	518.5	WR	4/1/1993										0	288	From WOGCC (2014) "In April 1993, additional Wind River Sands were selectively perforated between 1,701' and 2,388', and were not stimulated.	Yes
	980.8	WR	1/5/1980		17.93	25.0	33.78	6.89		X		29,484			On 1/5/1980, "A.T. BWR perfs...4100 gals 15% HCl containing 2 gals inhibitor 2 gals surfactant 4 gals clay stabilzer & 35# iron sequestering agent/1000 gals acid 4100 gallons 15% HCL, 2 gallons inhibitor, 2 gallons surfactant, 4 gallons clay stablizer, 35 pounds iron sequestering agent per 1000 gallons acid." On 1/10/1989 "frac treat basal W.R. w/50,000 gal Titan III-30 gel" and B-11 gel breaker (1# per 1000 gal). "Flushed to top perf w/1000 gals 2% KCl slicked w/3# per 1000 gal FR-16. All frac fluid contained 1 gal per 1000 clay master 1 gal per 1000 aqua flow - 2% KCl 1/2 gal per 1000 ASP 248."	
	1069.8	FU	12/21/1979		13.10	4.0		6.21		X					"A.T…w/700 gals 15% HCl…flushed w/16 bbls."	
	1243.6	FU	12/18/1979		13.10	7.0		5.17		X					"Acid treat…w/3500 gals 15% HCl containing 2 gals inhibitor 2 gals surfactant, 4 gals clay stabiizer 35# iron sequestering agent per 1000 gals acid...flushed w/19 bbls fluid."	
	1307.6	FU	12/12/1979		13.79	7.5	15.86	5.86		X					"Acidize gross Ft. Union…w/6400 gal 15% HCl 13 gal I-15 13 gal foam X, 26 gal clay master 225# X R-2…Displaced w/20 bbls clay stabilized water."	

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	1432.6	FU	12/10/1979		15.17		17.24	7.93		X					"Acidized FT. Union…w/4000 gal 15% HCL cont. 8 gal A-200 inhibitor, 8 gal M-38W surfactant, 16 gal L-53 clay stabilizer, 140 # L-41 iron sequestering agent…Displaced w/31 bbls fresh water containing 10 gal L-53 clay stabilizer."	
	1500.2	FU	12/10/1979							X					"4000 gal HCl"	
	1511.8	FU	12/10/1979							X					"4000 gal HCl"	
11-14	991.2	WR	2/5/1980							X			5	12,550	"3600 gal HCl"	No
	1544.1	FU	2/3/1980							X					"2500 gal HCl"	
	1564.2	FU	2/3/1980							X					"2500 gal HCl"	
16-28															Perforations from 3714'-3736'. Well completion report not available.	No
1-17															P&A after completion in 1980. No apparent production well casing. No stimulation or production.	No
14-2	481.9	WR	8/27/1982			0.69				X			0	44	On 11/12/1980, "Hit water flow while drilling at 4105'-4109'…Drilling fluid was contaminated with water…crews attempted to reduce viscosity with the additional of diesel…the diesel and the contaminated drilling fluid did not mix in the wellbore, instead the diesel replaced the weighted mud causing a reduction in hydrostatic head…the well started to flow and was closed in." On 8/24/1982, "Pmpd 800 gals 15% HCl contng 2 gals M38 w/2 gals A-200+4 gals of L-53+#L-41...Displaced w/9.5 bbls 2% KCl. On 8/25/1982, "Pumped 2000 gals 15% HCl…HCl contained 4 gals 38W + 4 gals A200 + 8 gals L-53 + 200 gals alcohol + 70# I-41. Pumped 2 bbls 2% KCl behind acid." Perforated at 20 depths from 1581-2980. "displace acid w/75 bbls 2% KCl"	Yes
	664.5	WR	4/1/1981							X					"800 gal 15% HCl containing 2 gals M38 W/2 gal A-200 + 4 gals L-53 + # L-41, 9.5 bbls KCl	
	1039.1	FU	4/14/1981			8.62				X					"Spotted 3 bbls 15% HCl…pmpd 23 bbls 15% HCl.26 bbls 15% HCl…pmpd 5 bbls 4% KCl …to flush casing." On 4/16/1981, "bullheaded 100 bbls 4% KCl down csg…spotted 3 bbls 15% HCl…saw 4 perfs open up. Pmpd 23 bbls 15% HCl."	
	1148.2	FU	4/9/1981			7.93				X					From WOGCC (2014) "acidized"	
	1189.3	FU	4/3/1981	17.93		17.93		3.10		X					"Spotted 21 bbls HCl…took 2 hrs to pmp 10 bbls into form…pmpd 22 bbls flush"	
	1370.1	FU	3/27/1981		26.20	17.0	27.58			X		23,587			"Pmp'd 20 bbls 15% HCl w/additives…pumped 30 bbls acid…flushed backside w/5 bbls KCl. On 3/30/1981, "frac as follows…143 bbls Apollo 30 pad…24 bbls gel…48 bbls gel…72 bbls gel…72 bbls gel…21 bbls 4% KCl flush."	
	1405.7	FU	3/27/1981		24.13	17.0	26.20	7.58		X					"Pmp'd 26 bbls acid…followed w/24 bbls flush…flushed backside w/5 bbls KCl wtr…Frac…as follow-100 bbls Apollo 30 pad…40 bbls Pad…24 bbls gel…48 bbls gel…72 bbls gel…72 bbls gel…flushed w/21 bbls 4% KCl."	
	1481.3	FU	3/20/1981	37.23	22.75	17.0	27.58	8.27		X		9,072			"Pmpd 12 bbls acid...pumped 12 bbls acid...pmpd 24 bbls acid...pmpd 12 bbls acid...Displaced acid w/26 bbls KCl wtr...Pumped 48 bbls YF4PSD pad. 24 bbls gelled wtr." then 180 bbls YF4PSD. Materials charged for in frac include 700 lbs J-347 gelling agent, 48 lbs J-218 breaker, 16 gal J-318 breaker aid, 32 gal L-53 clay stabilizer, 5 gal D-47, 5 gal MW38 surfactant, A-200 inhibitor, U42"	
1-8-1B															P&A after completion in 1981. No apparent production well casing. No stimulation or production.	No
21-9	657.8	WR	6/15/1981										0	11	Information missing from well completion report but reviewed by WOGCC (2014). Well schematic in WOGCC (2014)	Yes
	725.4	WR	6/8/1981			6.89				X					"Acidized" from WOGCC (2014)	
	796.7	WR	6/6/1981			6.89				X					"Acidized" from WOGCC (2014)	
	1022.9	FU	5/28/1981			23.44				X		11,754			WOGCC (2014) indicates that this interval was stimulated with "357 barrels of gelled water."	
	1129.3	FU	5/26/1981			11.72				X					"Acidized" from WOGCC (2014)	
	1209.1	FU	5/21/1981			11.72				X					"Acidized" from WOGCC (2014)	
	1295.1	FU	5/20/1981			11.72				X					"Acidized" from WOGCC (2014)	

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (MPa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
	1340.5	FU	5/18/1981			8.27				X					"Acidized" from WOGCC (2014)	
	1362.8	FU	5/16/1981			12.41				X					"Acidized" from WOGCC (2014)	
	1426.2	FU	5/7/1981			7.58				X					"Acidized" from WOGCC (2014)	
	1468.8	FU	4/29/1981			15.17				X					"Acidized" from WOGCC (2014)	
	1530.1	FU	5/2/1981			10.34				X					"Acidized" from WOGCC (2014)	
12-3		WR ?											0	1,970	Production of gas and water production in WR formation in 2005. Stimulation unknown.	No
		FU ?													Prodution of gas production in FU Formation in 1993. Stimulation unknown.	
	1481.0	FU	7/8/1981							X					"6500 gals HCl"	
RH 1															P&A after completion in 1981. No apparent production well casing. No stimulation or production.	No
1-4	587.0	WR	6/28/2001										5,982	10,417	3 perforated intervals from 1926'-2136'. No information on stimulation.	No
	699.2	WR	5/20/1982							X		28,123			"2000 gal 15% HCl, 26,000 gal 75% foam"	
	982.7	WR	5/20/1982							X					"1600 gal 15% HCl, 500 gal NH4Cl, 1500 gal 3% HF, 12% HCl"	
14-24	1007.7	WR	8/24/1982							X					"Acidized" P&A in 1982 after completion. No production.	No
	1041.8	FU	8/24/1982					11.37		X					"Acidized"	
A-1	679.7	WR	4/20/1983							X			155	7,072	"1000 gal + 1000 gal acetic acid" squeeze and reperf "1500 gallons HCl." Completion date used.	
	727.3	WR	4/20/1983							X		18,597			"4000 gallons HCl, 32,000 gal foam" Completion date used.	
1-15	4522.0	C	7/27/1983							X			1,116	19	"21000 gallons of acid" in Cody Formation	No
	4722.9	C	7/27/1983							X					"20 bbls KCl, 275 gal gel water" in Cody Formation	
B-1	900.7	WR	9/19/1984							X		499			"6000 gallons diesel + additives"	No
	1465.5	FU	9/19/1984							X					"6878 gallons 7½ % HCl SC + HCl-HF"	
	1556.9	FU	9/19/1984							X					"2100 gal 7½%+15% HCL + additives"	
33-11	510.8	WR	2/5/2002	15.72	15.51	25.0		8.91		X		7,180	333	4,972	"BD w/6% KCl…Frac using 75Q CO2, 42 bbls gel, 16 ton CO2…flush w/50% CO2."	No
	570.9	WR	2/5/2002	16.20	12.41	25.0		7.45		X		7,057			"Frac-BD w/6% KCl…Frac using 142 bbls 75Q CO2, 42 bbls gel, 16 tonCO2…42 bbls 6% flush."	
	601.1	WR	2/5/2002	12.27	13.79	25.0				X		8,074			"Frac-BD w/6% KCl…Frac using 162 bbls 75Q CO2, 47 bbls gel, 18 tons CO2…48 bbls w/6% KCl."	
	627.3	WR	2/5/2002	10.69	12.07	25.0				X		8,185			"Frac-BD w/6% KCl…Frac using 164 bbls 75Q CO2, 47.5 bbls gel, 18 ton CO2, 48 bbls 6% KCl flush."	
	855.9	WR	2/5/2002	11.72	13.79	25.0				X		7,031			"Frac-BD w/6% KCl…Frac using 143 bbls 75Q CO2 foam, 42 bbls gel, 17 tons CO2…85 bbls 6% KCl flush."	
	1091.2	FU	9/8/1993							X					"Acidize each zone w/500 gals 7 1/2" NEFE" [3580-3592 and 3815-3939 - total 1000 gals NEFE].	
	1160.4	FU	9/9/1993		21.86	21.0	26.89	7.24		X		28,123			"Acidize each zone w/500 gals of 71/2" NEFE."[3807-3813 and 3830-3851-total 1000 gals NEFE]."Frac well down tbg & csg w/33,650 gal CO2 foam frac,70Q."	
12-11	1030.8	FU	11/23/2004		16.01	22.8	20.77	10.86	20.81	X		9,072	229	8,451	"Frac…70Q CO2…total load 107.1 bbls"	Yes
	1085.7	FU	11/23/2004		9.14	22.4	14.73	6.07	15.83	X		18,144			"Frac…70Q CO2…total load 175.1 bbls"	
	1101.5	FU	11/23/2004	9.38	4.56	24.4	9.38	2.28		X		18,144			"Frac…70Q CO2…total load 196 bbls"	
	1141.8	FU	11/23/2004	16.13	7.52	24.4	17.57	4.93		X		18,144			"Frac…70Q CO2…216.8 bbl total load"	
	1164.9	FU	11/5/2004	8.96	7.21	25.2	11.11			X		24,149			"200 bbls water…CO2 assist"	
	1333.2	FU	10/30/2004	9.05				2.86		X		6,810			"Sand can broke down 300# sand. Go to flush. Over flush 30 bbl…Frac…210 bbl clean fluid + 253 from previous 463 total…40 tons CO2."	
	1398.1	FU	10/19/2004	11.49		40.68		8.27		X		8,381			"128 bbl clean fluid, 29 tons CO2"	
	1449.0	FU	10/14/2004	16.44	38.61	25.0		5.23		X		19,257			"36 bbl clean fluid…36 tons CO2"	
	1574.9	FU	10/12/1993			18.74				X		32,704			"Frac...with CO2 foam frac consisting of 11,819 gal of 2% KCl water plus 120 tons CO2...total load 2% KCl 279 bbls."	

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	1624.9	FU	10/12/2004		37.23	25.0		10.25		X		14,197			"Frac…39 tons CO2 and 208 bbl clean fluid"	
11-10	800.7	WR	10/15/2004	11.18	9.56	21.4		6.98		X		8,165	1,238	21,643	Information on fluids used for stimulation not available.	No
	818.7	WR	10/15/2004	5.70	6.49	15.4		7.02	18.55	X		8,165			Information on fluids used for stimulation not available.	
	858.0	WR	10/14/2004	18.96	10.92	18.6				X		6,804			Information on fluids used for stimulation not available.	
	897.9	WR	10/14/2004	5.35	10.71	16.6			20.36	X		6,804			Information on fluids used for stimulation not available.	
	920.5	WR	10/8/2004	9.38	15.17	35.0		10.38		X		8,165			"frac…129 bbls clean fluid, 29 tons CO2"	
	971.7	WR	10/8/2004	12.71	22.75	32.0		10.55	20.81	X		5,443			"144 bbls clean fluid, 19 tons CO2"	
	1049.4	FU	6/20/2005	16.29	22.06	30.0		11.20		X		13,608			"frac…232 bbl clean fluid, 39 tons CO2"	
	1358.2	FU	10/8/2004	7.05	8.96	30.0		4.24		X		19,051			"frac...359 clean fluid, 54 ton CO2"	
	1462.7	FU	9/3/2004		20.17	24.2	38.74	1.78	11.54	X		24,494			"CO2 frac 226 bbls total load…recovered 37 bbls of 226 bbl load."	
	1528.9	FU	9/2/2004		21.52	18.5	50.81		15.16	X		14,969			"fraced down…12,887 gal CO2…7OQ…pad volume 3952.6 gal total load 195 bbls…blew rupture disk on #1 CO2 pump…recoverd 41 bbls of 195 bbl load."	
42-10	762.6	WR	12/20/2004	9.11	8.46	12.67		8.32	21.04	X		6,804	595	14,503	"Total load 86.1 bbls." Treatment report available for 2004 stimulation events.	Yes
	807.1	WR	12/15/2004	9.74	8.27	13.31		7.35		X		6,871			"Frac 122 bbls slickwater" From stimulation report posted 8/9/2013, 4351 gal 70Q CO2 WF12 consisted of 4351 gal water and 34 lb J216."	
	1005	WR	6/24/2001	12.82	12.07	25.0	12.41	7.70		X		9,072			"frac...Flush w/50Q CO2 foam"	
	1034	FU	6/23/2001	9.51	15.51	30.0	15.51			X		5,859			"frac" No information on stimulation fluids.	
	1068	FU	6/23/2001	6.16	10.69	35.0	11.89	6.48		X		9,072			"frac" No information on stimulation fluids.	
	1202	FU	6/22/2001	10.16	13.51	35.0	13.44	7.36		X		11,340			"frac...70Q CO2 foam…total clean fluid 267 bbls."	
	1239	FU	6/22/2001	10.07	10.82	30.0	11.55	9.27		X		11,340			"frac…clean fluid 197 bbls"	
	1256	FU	6/22/2001	6.52	13.44	36.0	10.00	6.83		X		7,525			"frac…pumped 84 bbls clean fluid"	
	1380	FU	6/22/2001	5.80	10.51	35.0	10.51	6.14		X		11,340			"frac…total clean fluid 302 bbls, 89.5 tons CO2"	
	1448	FU	9/16/1994							X					In sundry notice dated 5/27/2005, "Acidize w/2000 gallons 15% NEFE, 2300# rock salt". WOGCC (2014) states "no treatment" at this depth.	
	1620	FU	6/13/1994							X					"Perf 5315-39, 5389-5403', 5476-86...acidize w/1250 gal 7 1/2% HCl acid (6/13/94). On 6/12/2001, "Acidize - Stage 3 (5315-5339') Pump 750 gal 15% HCl...750 gal 15% drop 48 balls, 700 gal & flush."	
	1643	FU	6/12/2001							X					"Stage 2 (5389-5403') Pump 700 gal 15% HCl, 250 gal 6% KCl w/28 frac balls, 700 gal 15% HCl" Stimulation at this interval not reported by WOGCC (2014).	
	1669	FU	6/12/2001							X					"Stage 1 (5476-5486) Pump 900 gal 15% HCl, 10 bbls 6% KCl, w/30 frac balls, 500 gal 15%" Stimulation at this interval not reported by WOGCC (2014). Modified wellbore schematic available in WOGCC (2014).	
31-10	1017	FU	1/16/2002	11.30	15.17	30.0		6.14		X		8,211	1,412	15,504	"Break w 6% kcl…start 70Q foam 242 bbl, 80 bbl fluid, 29 ton co2…77 bbl 40Q flush"	Yes
	1095	FU	1/16/2002	10.69	14.48	35.0		8.27		X		12,527			"Break w 6% kcl…start 70Q co2 foam, 405 bbl, 151.5 bbl fluid, 39 ton co2"..flush w 84.5 bbl 6% kcl"	
	1377	FU	1/15/2002	12.07	15.86	35.0		6.03		X		20,550			"Break w 6% kcl…start 70Q co2, 695 bbl foam, 232 fluid, 74 ton co2…flushed 50% co2 bbl."	
	1411	FU	1/15/2002	14.13	16.89	35.0		8.80		X		10,704			"Break w 6% kcl…start 70Q co2 foam, 254 bbls fluid, 36 ton co2…flush was 109.5 bbl 6% kcl."	
	1362	FU	6/22/1994							X					In sundry notice dated 5/28/2002, "Acid frac…each & all sets of perfs w/600 gals 7 1/2% HCl acid each 4770'-5478'."	
23-10	1400	FU	7/8/2000	9.10	6.03	30.0		7.03		X		22,389	7	112,463	"Pump 70Q CO2 foam fr ac…3000 gals pad, 480 gals…540 gals…640 gals…812 gals…1200 gals…3696 gals 50Q flush…pumped 226 bbls KCL, 47 ton CO2."	Yes
	1476	FU	6/29/2000	14.92	8.27	28.5		4.27		X		12,519			"Pumped 70Q CO2 foam frac…3000 gal pad, 1700 gal…1840 gals…2843 gals 50Q flush."	
	1620	FU	8/8/1994							X		14,742			"500 gal 15% HCl" "Frac w/16500 gal plus 700 N2 foam."	
43-10	1389	FU	2/6/2002	11.86	19.31	35.0		5.28		X		21,896	606	28,467	"Frac break w/6% KCL …Frac using 547 bbls 70Q CO2 foam, 125 bbls gel, 63 ton CO2…flush w/30% CO2."	Yes

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	1467	FU	2/6/2002	11.24	17.24	35.0		5.16		X		28,931			"Frac-Break w/6% KCL…Frac using 837 bbls 70Q CO2, 235 bbls gel, 95 tons CO2…112 bbls 6% KCl flush."	
	1574	FU	2/6/2002		20.34	34.0				X		15,941			"Frac using 457 bbls 70Q foam, 130 bbls gel, 52 ton CO2…flush w/120 bbls 6% KCl."	
	1597	FU	2/6/2002	20.48	24.13	32.0		14.89		X		19,595			"Frac using 545 bbls 70Q CO2…156 bbls gel, 61 ton CO2…flush w/124 bbl 6% KCl."	
	1623	FU	9/20/1994		19.31			19.54			X				Sundry notice dated 2/19/2002, "Picke tbg w/600 gal 15% acid. Spot 250 g 15% NEFE acid…press tbg to 5300 psi w/N2…Pump 20 mcf N2 @ 2100 scfm @ 2800 psi" WOGCC (2014) indicates no stimulation at this depth.	
	1678	FU	1/26/2002		16.41	50.0		7.93		X		30,551			"Frac-total pumped 317 bbls KCl, 598 bbls CO2"	
33-2	432.8	WR	10/18/2000							X		8,245	0	1,263	"Coil frac...104 bbls clean fluid, 41300 scf of N2."	No
	552.3	WR	10/18/2000							X		4,954			"Coil frac...93 bbls clean fluid, 43300 scf of N2."	
	605.6	WR	10/18/2000							X		10,870			"Coil frac...177 bbls clean fluid, 961000 scf of N2"	
	624.5	WR	10/18/2000							X		13,525			"Coil frac...139 bbls clean fluid, 77100 scf of N2"	
	644	WR	10/18/2000							X		15,037			"Coil frac...206 bbls clean fluid, 124200 scf of N2"	
	680.6	WR	10/18/2000							X		8,698			"Coil frac...126 bbls clean fluid, 78000 scf of N2"	
	715.1	WR	10/18/2000							X		12,701			"Coil frac...183 bbls clean fluid, 115800 scf of N2"	
	750.1	WR	10/18/2000							X		17,049			"Coil frac...254 bbls clean fluid, 162300 scf of N2"	
	776.6	WR	10/18/2000							X		12,927			"Coil frac...317 bbls clean fluid, 83800 scf of N2"	
	849.2	WR	10/21/1994								X				"Acidize...w/300 gals 15% NEFE"	
	862	WR	10/21/1994								X				"Acidize...w/300 gals 15% NEFE"	
	904.3	WR	10/21/1994								X				"Acidize...w/300 gals 15% NEFE"	
23-1	810.5	WR	10/13/1994		11.40	5.0	12.34	5.38			X		0	480	"Spot & pump 400 gal 15% NEFE…gained 30.48 bbls in 72 hrs 15,000 ppm chl."	No
	857.7	WR	10/13/1994		12.25	5.0	14.13	5.38			X				"Spot & pump 400 gal 15% NEFE"	
	907.1	WR	10/13/1994		11.07		16.76	7.93			X				"Spot & pump 400 gals 15% NEFE"	
	1393	FU	8/13/1994		17.33		18.60	6.23			X				"Pump 500 gals 15% NEFE"	
	1526	FU	8/13/1994		21.28		23.39	7.96			X				"Spot & pump 500 gals 15% NEFE."	
41-15	1650	FU	11/2/1994		10.34	3.0	39.09	40.09		X		14,742	355	64,192	"1500 gal 15% NEFE-PB", "frac w/16,600 gal 65Q N2 foam."	No
	1897	FU	11/2/1994								X				"2000 gal 15% NEFE-PB...gained 3.34 bbl in 1 hr…(11,000 ppm chl)"	
43-6	287.7	WR	8/10/1999		6.62	6.0		1.57			X		0	1,062	300 gal "7.5% HL w/mutual solvent, HC2 surfactant, flush 4% KCl"	No
	359.1	WR	8/10/1999		8.55	6.0		4.24			X				400 gal "7.5% HL w/mutual solvent, HC2 surfactant, flush 4% KCl"	
	379.2	WR	8/10/1999		13.79	6.5		4.92			X				150 gal "7.5% HL w/mutual solvent, HC2 surfactant, flush 4% KCl"	
	476.1	WR	8/10/1999		12.07	6.6		5.54			X				250 gal 7.5% HL w/mutual solvent, HC2 surfactant, flush 4% KCl"	
	548.6	WR	8/10/1999		12.07	6.8		4.08			X				1000 gal "7.5% HL w/mutual solvent, HC2 surfactant, flush 4% KCl"	
	575.5	WR	8/10/1999		12.76	6.0		4.59			X				1000 gal 7.5% HL w/mutual solvent, HC2 surfactant, flush 4% KCl"	
	723.6	WR	8/4/1999					7.38		X		21,387			"clear frac"	
	751.6	WR	8/4/1999					8.61		X		18,079			"clear frac"	
	1055	WR	5/23/1995								X				"Pmp 100 gals 15% HCl acid & 95, 180 SCF/N2"	
23-11	507.2	WR	10/14/2000							X		4,975	88	208	"Coil frac...81 bbls clean fluid, 34600 scf N2"	No
	522.1	WR	10/14/2000							X		20,936			"Coil frac...282 bbls clean fluid, 141000 scf N2"	
	554.1	WR	10/14/2000							X		7,967			"Coil frac...119.5 bbls clean fluid, 59400 scf N2"	
	607.5	WR	10/14/2000							X		7,976			"Coil frac...117 bbls clean fluid, 64100 scf N2"	
	739.7	WR	10/14/2000							X		5,993			"Coil frac...96 bbls clean fluid, 62100 scf N2"	
	792.2	WR	10/12/2000							X		9,617			"Coil frac...136 bbls clean fluid, 10700 scf N2"	

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	802.5	WR	10/12/2000							X		7,128			"Coil frac...102 bbls clean fluid, 71900 scf N2"	
	843.1	WR	10/12/2000							X		12,226			"Coil frac...198.6 bbls clean fluid, 168,000 scf N2"	
	866.2	WR	10/12/2000							X		4,652			Coil frac...86.2 bbls clean fluid, 69000 scf N2"	
	1054	FU	3/5/2005	7.78				8.42		X		8,649			"Frac: 4172 bbls 70Q"	
	1103	FU	3/2/2005	4.94				3.25		X		13,166			"Frac: 181 bbls 70Q"	
	1159	FU	2/23/2005	11.03				3.72		X		13,114			"Frac: 9348 bbls 60Q"	
	1358	FU	3/6/1998							X					"Acidize w/300 gals 7.5% HCl"	
	1388	FU	1/19/1998							X					"Acidize w/1000 gallons 15% HCl"	
	1403	FU	12/17/1997							X					"Acidize w/500 gal 15% HCl, flush w/brine"	
	1458	FU	12/4/1997							X					"Acidize w/500 gal 15% HCl…Frac-Delta frac-30% N2 used except flush. Total 742.3 bbls"	
	1558	FU	11/25/1997							X					"Acidize w/500 gal 15% HCl"	
	1581	FU	12/2/1997							X					"Acidize w/500 gal 15% HCl"	
	1653	FU	11/21/1997							X					"Acidize w/500 gal 15% HCl"	
31-11X	2828	C	10/22/1998										1,666	8,797	Hydraulic fracturing in Lance, Meetesse, Mesa verde, and Cody Formations. Acidize with 18,500 gallons 15% HCl. Frac w/1015 bbls CO2 foam	No
13X-3	410.9	WR	2/18/1999		7.58	1.5		5.40		X			0	0	"Acd…w/400 gal 15% HCl"	
	527.3	WR	2/18/1999		3.79	1.5		3.25		X					"500 gal HCl"	
	584	WR	2/18/1999		9.24	1.6		7.65		X					"Acd…w/300 gal HCl"	
	635.2	WR	2/18/1999		6.21	1.5		5.10		X					"Acd…w/250 gal HCl"	
	640.4	WR	2/18/1999							X					"Acd…pmpd 73 gal HCl"	
	676.7	WR	2/18/1999							X					"Acd…w/250 gal"	
	689.2	WR	2/18/1999		5.52	1.5		4.73		X					"Acidize w/250 gal 15% HCl"	
	1179	FU	2/15/1999			4.0		0.26		X					"Acidize…w/1000 gal 15% HCl…disp w/2% KCl…Fluid pmp 41.5 bbl, fluid recvrd 12.6."	
	1381	FU	2/9/1999					0.06		X					"500 gal HCl"	
	1489	FU	2/9/1999							X					"500 gal HCl"	
	1510	FU	2/9/1999					6.35		X					"500 gal HCl"	
	1558	FU	2/9/1999					2.95		X					"500 gal HCl"	
42X-9		FU											100	10,083	Completed in Fort Union Formation. Information on perforations and stimulation missing from well completion report.	No
41-11	602.3	WR	2/1/1999							X			0	207	"Acidize…w 1100 gallons 15% HCl"	No
	622.1	WR	2/1/1999			6.41	1.61			X					"Acidize …w/300 gallons 15% HCl each [perforated interval] (600 gals total)"	
	648.6	WR	2/1/1999			6.48	1.50			X					"Acidize…w/300 gallons 15% HCl each [perforated interval] (600 gals total)"	
	793.7	WR	1/28/1999	11.89	8.84	3.8	13.66			X					"Acidize w/1500 gallons 15% HCl"	
	1033	FU	1/21/1999		12.41	4.1		0.85		X					"Acidize…w/500 gallons 15% HCl"	
	1054	FU	1/21/1999		11.79	4.1		4.63		X					"Acidize…w/500 gallons 15% HCl"	
	1183	FU	1/21/1999		7.58	4.0		0.99		X					"Acidize…w/1000 gallons 15% HCl"	
	1384	FU	1/19/1999	18.89	15.86	4.5		7.04		X					"Acidize…w/1000 gallons 15% HCl"	
	1527	FU	1/11/1999	12.62	12.27	3.1		7.29		X					"Acidiz…w/500 gallons HLC" [HCl]	
33-10	640.4	WR	1/5/2005	11.29	13.13	24				X		9,525 2		2,547	"28 tons CO2"	Yes
	740.1	WR	1/5/2005	6.58	7.43	16.0		6.96		X		8,165			"24 tons"	
	756.5	WR	1/4/2005	13.29	10.74	23.5		8.69		X		10,886			"32.6 tons CO2, 148 bbls 6% KCl"	
	1146	FU	1/4/2005	12.40	8.05			3.99		X		9,525			"170 bbls 6% KCl, 28.6 tons CO2"	

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (MPa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
	1192	FU	1/4/2005	9.20				6.12		X		6,763			"71.2 bbls CO2"	
	1562	FU	4/20/1999		12.14	33.0	15.55	10.84		X					"Frac w/35# liner [linear] gel & 70% CO2 foam. Total fluid pmped 10,235 gals & 76.5 tons CO2."	
	1637	FU	4/12/1999		13.55	25.0		10.45		X		24,902			"Acidize w/1500 gal 15% HCl. Frac...35# linear gel w/70% CO2…total fluid pmped 13,754 gal. Total CO2 68 tons."	
33-3	1372	FU											0	337	Perforated intervals in Wind River and Fort Union Formations. Production from Wind River Formation. Information on stimulation missing.	No
44-3	213.1	WR	4/8/1999		7.58			2.30		X			1	1,663	"Acidize…w/500 gals 15% HCl"	Yes
	505.4	WR	4/8/1999		9.65	15.0	12.41	8.84		X		46,090			On 4/8/1999, "Acidize…w/500 gals 15% HCl" On 5/26/1999, "frac…w/273 bbl clear frac" ISIP for acid stimulation was 3.63 MPa.	
	634.3	WR	4/8/1999		10.34	5.0		6.72		X					On 4/8/1999, "Acidize…w/500 gals 15% HCl" On 6/2/1999, "frac…w/243 bbl clear frac". ISIP for acid stimulation was 1.03 Mpa.	
	679.7	WR	4/8/1999		6.82	3.0		4.92		X					"Acidize…w/200 gals 15% HCl"	
	838.8	WR	4/8/1999		11.20	5.3		3.06		X					"Acidize…w/500 gals 15% HCl"	
	849.8	WR	4/8/1999		11.38	5.0		3.45		X					"Acidize w/300 gals 15% HCl"	
	1070	FU	3/23/1999					5.69		X					"Pmp 7 bbl 15% HCl and 5 bbl 2% KCl…displ acid w/10 bbl 2% KCl…reset pkr, pmp 2% KCl…at 1000 psi…load pmpd 38 bbl"	
	1080	FU	3/23/1999							X					"Acidize…w/5 bbls [HCl]"	
	1183	FU	3/16/1999	6.49	13.79	6.0		3.03		X					"Acidize…w/500 gals 15% HCl"	
	1214	FU	3/9/1999	6.34	10.34	6.0		3.56		X					"Acidize…w/500 gals 15% HCl"	
	1322	FU	3/5/1999			3.0		3.85		X					"Acidize…w/950 gal 15% HCl"	
	1361	FU	3/5/1999			5.0		0.15		X					"pmp 420 gal 15% HCl"	
	1451	FU	2/25/1999			4.0		4.83		X					"Breakdown on perf w/1250 gal 15% HCl"	
15-21X	1196	FU	2/9/2001	6.21	4.83	4.0				X			161	1,276	"Pmp 20 bbls 6% KCl…pump 20 bbls 6% KCl"	No
	1617	FU	2/7/2001	10.34	3.45	2.0				X					"Pmp 10 bbls 6% KCl"	
	1652	FU	2/2/2001	10.34	4.14	2.0		2.41		X					"Pump 10 bbls…Acidize w/15 bbls 7 1/2% acid, flush w/52 bbls KCl water…no flow back"	
	2711	M	12/5/2000												"Acidize w/41 bbls prod wtr…pump 5.6 bbls more/pump 11.7 bbls 15% HCl & over flush perfs"	
	4659	F	1/27/1999												"Pmp perfs w/3000 gals diesel & 1000 gal pad acid"	
	4709	F	1/6/1999												"Suspected casing collapse @ 15273...Breakdown w/4000 gal diesel w/FE 1A Hyflo IV, Musol A"	
	4868	F	12/6/1998												"Breakdn w/2000 gals diesel w/20 gal Hyflo IV, 100 gal Musol A…No circulation before or during cement job; lost 1100 bbls mud [invert] before job"	
32-10	1617	FU	5/12/2000		7.58	25.0		4.62		X			29	2,200	"Frac w/24,096 gal CO2 foam "	Yes
	1661	FU	5/3/2000					4.94		X					"Acidize w/1000 gal 7.5% HCl, flush 909 gals 4% KCL. Frac w/16054 gals 70Q CO2 foam." ISIP for acid stimulation = 0.94 Mpa.	
13-11	764.4	WR	2/21/2001		16.55	26.0		6.62		X			0	431	"Frac…using 231 bbls wf 135 in 6% KCl water w/10% methanol + adds, 59 tons CO2...573 bbls 70Q CO2 foam. Flush w/37 bbls KCl w/10%"	No
	807.1	WR	2/21/2001		15.86	25.0		8.58		X					"Frac…using 100 bbls wf 135 in 6% kcl w/10% methanol + adds, 24 tons CO2...258 bbls 70Q CO2 foam. Flush w/40 bbls 6% kcl w/10% methanol."	
	849.8	WR	2/20/2001		16.55	30.0		9.24		X					"Frac…using 130 bbls wf 135 in 6% KCl water w/10% methanol + adds, 35 ton CO2...359 bbls 70Q CO2 foam. Flush w/42 bbls 6% kcl water w/10% methanol."	
	1103	FU	2/20/2001		7.58	25.0		7.48		X					"Frac…using 276.2 bbls wf 135 in 6% kcl water w/10% methanol + adds, 90 tons CO2...849 bbls 70Q CO2 foam. Flush w/55 bbls 6% kcl wtr w/10% methanol."	

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	1390	FU	2/20/2001		20.68	33.0		7.38		X					"Frac…using 174.5 bbls wf 135 in 6% KCl wtr w/10% methanol + adds, 40 tons CO2...433 bbls 70Q CO2 foam. Flush w/69 bbls 6% kcl wtr w/10% methanol"	
	1544	FU	2/15/2001	11.72	9.65	2.5				X						
21-13	504.1	WR	2/17/2001	11.38	11.72	30.0		8.27		X		10,886 2		1,422	"Frac…using 98 bbls wf 135 in 6% kcl water w/10% methanol + adds, 28 tons CO2...275 bbl 70Q CO2 foam. Flush w/33 bbls 6% kcl w/10% methanol."	Yes
	651.1	WR	2/17/2001	18.62	17.93	30.0		8.96		X		19,504			"Frac…using 170 bbl Wf 135 in 6% kcl water w/10% methanol + adds, 50 tons CO2... 488 bbls 70Q CO2 foam. Flush w/33 bbls 6% kcl w/10% methanol."	
	804.7	WR	2/17/2001	15.17	15.17	30.0		11.58		X		19,051			"Frac…using 174 bbl wf 135 in 6% KCl water w/10% methanol + adds, 51 tons CO2...264 bbls 70Q CO2 foam. Flush w/41 bbls 6% kcl wtr w/10 % methanol."	
43-2	502.9	WR	2/24/2001		0.97	35.0		6.83		X			0	97	"Frac…using 298 bbls wf 135 in 6% KCl water w/10% methanol + adds, 106 tons CO2...1000 bbls 70Q CO2 foam. Flush w/25 bbls 6% kcl w/10% methanol."Frac…using 174 bbl wf 135 in 6% KCl water w/10% methanol + adds, 51 tons CO2...264 bbls 70Q CO2 foam. Flush w/41 bbls 6% kcl wtr w/10 % methanol."	No
	603.5	WR	2/23/2001		12.82	27.0		7.79		X					"Frac...159 bbls wf 135 in 6% KCl water w/10% methanol + adds, 50 tons CO2...496 bbls 70Q CO2 foam. Flush w/30.5 bbls 6% kcl water w/10% methanol."	
	748.6	WR	2/23/2001		11.03	21.0		8.14		X					"Frac…using 156 bbls wf 135 in 6% methanol [typo 6% kcl water w/10% methanol?] + adds, 43 tons CO2...452 bbls 70Q CO2 foam. Flush w/38 bbls 6% KCl w/10% methanol."	
	902.2	WR	2/23/2001		14.24	30.0		10.76		X					"Frac…using 209 bbls wf 135 in 6% kcl wtr w/10% methanol + adds, 67 tons CO2...661 bbls 70Q CO2 foam. Flush w/46 bbls 6% kcl w/10% methanol."	
13-2	500.2	WR	1/11/2002	13.55	12.55	30.0		6.21		X			0	1,333	"Frac…totals pumped 104 bbls KCl, 153 bbls CO2"	No
	569.7	WR	1/10/2002	23.84	22.75	32.0		8.36		X					"Frac…totals pumped 121 bbls KCl, 245 bbls CO2"	
	671.2	WR	1/10/2002	23.69	22.75	29.0		7.84		X					"Frac…totals pumped 122 bbls, 192 bbls CO2"	
	766.6	WR	1/10/2002	24.82	19.99			7.10		X					"Frac…totals pumped 160 bbls KCl, 280 bbls CO2"	
	805.9	WR	1/10/2002	24.13	15.17	25.0		9.38		X					"Frac…totals pumped 95.6 bbls CO2, 136.6 bbls KCl"	
	856.8	WR	1/9/2002	21.68	17.93	30.0		9.97		X					"Frac using 75Q foam…totals pumped 158 bbls CO2, 131 bbls KCl"	
	923.5	WR	1/8/2002	20.48	47.57	20.0		9.84		X					"Frac-breakdown w/6.3 bbls KCl…Pumped 70Q foam pad 50Q san stages…Totals pumped 125 bbls KCl, 120 bbls CO2"	
24-1	432.2	WR	3/23/2001										0	817	Producing in Wind River Formation. Six perforated intervals from 1418' to 2964'. No information provided on stimulation.	No
32-1	371.9	WR	3/23/2001		9.26	22.0		5.45		X			0	102	"Frac…using 165 bbls wf 130 in 6% kcl water w/10% methanol + adds, 39 tons CO2...458 bbls 70Q CO2 foam. Flush w/18 bbls 6% kcl water w/10% methanol."	
	535.8	WR	3/23/2001		9.65	21.4		5.86		X					"Frac…using 153 bbls wf 130 in 6% Kkcl water w/10% methanol + adds, 35 tons CO2...398 bbls 70Q CO2 foam. Flush w/27 bbls 6% kcl water w/10% methanol."	
	648	WR	3/23/2001		12.89	21.9		8.14		X					"Frac…using 105 bbls wf 130 in 6% kcl w/10% methanol + adds, 21 tons CO2...232 bbls 70Q CO2 foam. Flush w/32 bbl 6% kcl water w/10% methanol."	
	856.5	WR	3/22/2001		8.69	21.0		7.29		X					"Frac…using 144.4 bbls wf 130 in 6% KCl water w/10% methanol + adds, 29 tons CO2...333 bbls 70Q CO2 foam. Flush w/43.8 bbl kcl water w/10% methanol."	
	917.4	WR	3/20/2001		15.72	30.0		9.47		X					"Frac…using 177.3 bbls wf 130 in 6% kcl w/10% methanol + adds, 38 tons CO2...332 bbls 70Q CO2 foam. Flush w/46 bbls 6% kcl w/10% methanol."	
34-2	385.3	WR	3/20/2001		8.46	18.0		6.00		X			0	414	"Frac…using 92.1 bbls wf 130 in 6% kcl w/10% methanol, 20 ton CO2...228 bbls 70Q CO2 foam. Flush w/18.5 bbls 6% kcl w/10% methanol.	No
	469.4	WR	3/17/2001		10.85	19.9		7.58		X					"Frac…using 70.8 bbls wf 130 in 6% kcl w/10% methanol, 14 ton CO2...149 bbls 70Q CO2 foam. Flush w/23.5 bbls 6% kcl w/10% methanol."	

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	497.4	WR	3/17/2001		7.47	18.0		5.10		X					"Frac…using 75.9 bbls wf 130 in 6% kcl w/10% methanol + adds, 14 ton CO2...160 bbls 70Q CO2 foam. Flush w/24 bbls 6% kcl water w/10% methanol."	
	554.7	WR	3/17/2001		10.98	19.0		7.58		X					"Frac…using 85.2 bbls wf 130 in 6% kcl water w/10% methanol + adds, 19 ton CO2...180 bbls 70Q CO2 foam. Flush w/28 bbls 6% kcl water w/10% methanol."	
	609.9	WR	3/17/2001		10.81	21.0		8.02		X					"Frac...using 175.3 bbls wf 130 in 6% kcl w/10% methanol + adds, 47.7 ton CO2...460 bbls 70Q CO2 foam. Flush w/31 bbls 6% kcl water w/10% methanol."	
	648.6	WR	3/17/2001		7.11	22.0		6.57		X					"Frac using 136.3 bbls wf 130 in 6% kcl water w/10% methanol + adds, 31 tons CO2...335 bbls 70Q CO2 foam. Flush w/33 bbls 8% kcl water w/10% methanol."	
	714.5	WR	3/16/2001		7.08	22.0		5.72		X					"Frac…using 190 bbls wf 130 in 6% kcl w/10% methanol + adds, 51.2 ton CO2...498 bbls 70Q CO2 foam. Flush w/36 bbls 6% kcl w/10% methanol."	
	793.1	WR	3/15/2001		13.44	20.0		8.89		X					"Frac…using 134 bbls wf 130 in 6% kcl w/10% methanol + adds, 21.5 ton CO2...242 bbls 70Q CO2 foam. Flush w/40 bbls 6% kcl w/10% methanol."	
	843.1	WR	3/15/2001		10.24	22.0		7.89		X					"Frac…using 86 bbls wf 130 in 6% kcl w/10% methanol + adds, 17 ton CO2...157 bbls 70Q CO2 foam. Flush w/43 bbls 6% kcl water w/10% methanol."	
	900.4	WR	3/15/2001		12.35	23.7		8.20		X					"Frac…using 128.4 bbls wf 130 in 6% kcl w/10% methanol + adds, 31 ton CO2...283 bbls 70Q CO2 foam. Flush w/46 bbls 6% kcl w/10% methanol."	
	986.6	WR	3/15/2001		10.81	30.0		7.54		X					"Frac…using 105 bbls wf 130 in 6% kcl w/10% methanol + adds, 20 ton CO2...192 bbls 70Q CO2 foam. Flush w/50 bbls 6% kcl water w/10% methanol."	
12-6													0	1,686	Producing from Wind River Formation. Information on perforation and stimulation missing from well completion report	No
44-1		WR											0	1,375	Producing from Wind River Formations (8 perforated intervals). Information on stimulation missing from well completion report.	No
14-10	639.5	WR	4/11/2001		14.09	21.9		8.27		X		10,565	3,678	3,225	"Frac…using 102.8 bbls wf 130 in 6% KCl w/10% methanol + adds, 24 tons CO2...219 bbls 70Q CO2 foam. Flush w/31 bbls 6% kcl water w/10% methanol."	No
	662	WR	4/11/2001		10.81	20.4		6.89		X		11,115			"Frac…using 112.6 bbbls wf 130 in 6% KCl w/10% methanol + adds, 25 tons CO2...219 bbl 70Q CO2 foam. Flush w/42.2 bbls 6% kcl water w/10% methanol."	
	872.3	WR	4/11/2001		9.83	20.5		7.31		X		20,342			"Frac…using 171.6 bbls wf 130 in 6% KCl water w/10% methanol + adds, 42 tons CO2...397 bbls 70Q CO2 foam. Flush w/44.5 bbls 6% kcl water w/10% methanol."	
	931.5	WR	4/11/2001		17.03	20.0		8.62		X		10,454			"Frac…using 121.6 bbls wf 130 in 6% kcl water w/10% methanol + adds, 24 tons CO2...224 bbls 70Q CO2 foam. Flush w/47 bbls 6% kcl water w/10% methanol."	
13-15	657.1	WR	5/17/2001	15.86	9.91	25.8		8.76		X		13,213	0	0	"Frac…using 120.2 bbls Wf125 in 8% KCl with 10% methanol, 38 tons CO2...277 bbls 80Q, 75Q, 70Q, and 60Q CO2 foam. Flush w/49 bbls 6% KCL w/10% methanol"	No
	754.7	WR	5/17/2001	5.60	7.74	23.8		4.48		X		16,442			"Frac…using 140.3 bbls Wf 125 in 8% KCl with 10% methanol, 45 tons CO2...325 bbls 80Q, 75Q, 70Q, and 60Q CO2 foam. Flush w/56.5 bbls 8% KCl w/10% methanol"	
	893.1	WR	5/17/2001	8.96	8.51	26.8		7.97		X		13,099			"Frac…using 138.9 bbls Wf 125 in 6% KCl with 10% methanol, 36 tons CO2...270 bbls 80Q, 75Q, 70Q, & 60Q CO2 foam. Flush w/67 bbls 6% KCl w/10% methanol"	
	1048	WR	5/16/2001	7.76	6.47	27.0		4.83		X		13,297			"Frac…using 153.6 bbls Wf 125 in 6% KCl w/10% methanol, 38 tons CO2…277 bbls 80Q, 75Q, 70Q, and 60Q CO2 foam. Flush w/79 bbls 8% KCl w/10% methanol"	
12-11W	770.8	WR	5/3/2001	11.86	9.07	24.7		6.87		X			0	460	"Frac…using 144.2 bbls wf 125 in 6% KCl water + adds, 37 tons CO2...290 bbls 70Q CO2 foam. Flush w/5 bbls 6% KCl w/10% methanol"	Yes
	843.4	WR	5/3/2001	2.76	7.51	21.5		6.62		X					"Frac…using 120.4 bbls wf 130 in 6% kcl water w/10% methanol + adds, 25 tons CO2…180 bbl 70Q CO2 foam. Flush w/63 bbls 6% KCl water w/10% methanol."	

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	864.1	WR	5/2/2001	15.17	10.14	22.4		7.69		X					"Frac…using 116.7 bbls wf 130 in 6% KCl water w/10% methanol + adds, 22 tons CO2... 170 bbls 70Q CO2 foam. Flush w/65 bbls 6% KCl w/10% methanol."	
	883.3	WR	5/2/2001	9.79	14.11	23.0		7.98		X					"Frac…using 131.2 bbls wf 130 in 6% KCl w/10% methanol + adds, 24 tons CO2...223 bbls 70Q CO2 foam. Flush w/66 bbls 6% KCl water w/10% methanol."	
	923.2	WR	5/2/2001	7.24	10.99	20.0		7.72		X					"Frac…using 146.4 bbls wf 130 in 6% KCl water w/10% methanol + adds, 27 tons CO2...251 bbls 70Q CO2 foam. Flush w/69 bbls KCl water w/10% methanol."	
34-3R	726.3	WR	5/4/2001		10.72	21.2		8.96		X			2	1,153	"Start frac & pump 86 bbl 80 Q CO2 foam…Leak on wellhead. Flush w/37 bbl kcl water…Start to frac again...Leak on wellhead again...Frac using 67.7 bbl wf 125 in 6% kcl water w/10% methanol + adds, 16 tons CO2...119 bbl 80Q CO2 foam. Flush w/37 bbl 6% kcl water w/10% methanol."	Yes
	773.6	WR	5/4/2001		11.13	22.6		7.93		X					"Frac…using 101.6 bbls wf 130 in 6% kcl w/10% methanol + adds, 24 tons CO2...207 bbls 70Q CO2 foam. Flush w/39.4 bbls 6% KCl water w/10% methanol."	
	809.2	WR	5/4/2001	16.84	13.48	27.2		8.55		X					"Frac…using 127.4 bbl wf 130 in 6% KCl water w/10% methanol + adds, 33 tons CO2…288 bbl 70Q CO2 foam. Flush w/41.3 bbls 6% KCl water w/10% methanol"	
	842.5	WR	5/4/2001	13.93	13.33	24.0		8.69		X					"Frac…using 108.8 bbl wf 130 in 6% KCl water w/10% methanol + adds, 29 tons CO2...26 bbls 70Q CO2 foam. Flush w/43 bbls 6% KCl water w/10% methanol."	
	942.7	WR	5/4/2001		11.84	21.5		9.65		X					"Frac…using 103.6 bbls WF 130 in 6% KCl water w/10% methanol + adds, 22 tons CO2...170 bbl 70Q CO2 foam. Flush w/48 bbls 6% KCl water w/10% methanol"	
11-11	1024	FU	5/31/2001	14.13	19.85	31.3		9.45		X		20,818	0	9,051	"Frac…using 161.2 bbls Wf 125 in 6% KCl water w/10% methanol, 45 tons CO2…441 bbls 70Q & 60Q CO2 foam. Flush w/50 bbls 50% CO2 & 50% - 6% KCl water w/10% methanol."	Yes
	1169	FU	5/31/2001		20.68	28.7		5.17		X		21,881			"Frac…using 200.3 bbls Wf 125 in 6% KCl water w/10% methanol, 50 tons CO2…466 bbls 70Q & 60Q CO2 foam. Flush w/58.5 bbls 6% KCl water w/10% methanol."	
	1238	FU	5/30/2001	24.82	18.73	22.2		13.44		X		15,708			"Frac…using 178.5 bbls Wf 125 in 6% KCl water w/10% methanol, 41 tons CO2…372 bbls 70Q & 60Q CO2 foam. Flush w/62.5 bbls 6% KCl water w/10% methanol."	
	1358	FU	5/30/2001	9.31	15.32	22.3		10.82		X		12,146			"Frac…using 153.1 bbls Wf 125 in 6% KCl water w/10% methanol, 28 tons CO2…262 bbls 70Q & 60Q CO2 foam. Flush w/68 bbls 6% KCl water w/10% methanol."	
	1380	FU	5/11/2001	24.34	21.35	24.0				X		16,594			"Frac…using 85.2 bbls Wf 125 in 6% KCl water w/10% methanol + adds, 45 tons CO2…334.8 [bbls] 80Q, 75Q, 70Q & 60Q CO2 foam. Screened out."	
	1394	FU	5/11/2001	24.61	15.49	25.4		9.85		X		12,207			"Frac…using 136.2 bbls Wf 125 in 6% KCl water w/10% methanol + adds, 38 tons CO2…258 bbls 80Q, 75Q, 70Q & 60Q CO2 foam. Flush w/70 bbls 6% KCl water w/10% methanol."	
	1467	FU	5/9/2001	20.51	15.55	28.5		8.41		X		18,033			"Frac…using 178 bbls Wf 125 in 6% KCl water w/10% methanol + adds, 58 tons CO2…417 bbls 80Q, 75Q, 70Q & 60Q CO2 foam. Flush w/70 bbls 6% KCl water w/10% methanol."	
12-5	571.2	WR	5/22/2001		12.41	18.0		6.50		X			0	3,402	"Frac…using 45.5 bbls 6% KCl w/10% methanol + 40 bbls CO2"	No
	609.6	WR	5/22/2001		13.48	31.0		7.63		X		15,291			"Frac…using 134.4 bbls WF125 in 6% KCl w/10% methanol, 40 tons CO2...332 bbls 70Q & 60 CO2 foam. Flush w/30.8 bbls 6% KCl water w/10% methanol."	
	665.4	WR	5/22/2001		15.55	29.4		7.72		X		12,783			"Frac…using 119 bbls WF125 in 6% KCl w/10% methanol, 32 tons CO2...267 bbls 70Q & 60Q CO2 foam. Flush w/33.7 bbls 6% KCl w/10% methanol."	
	748.9	WR	5/22/2001		15.50	28.3		7.93		X		10,389			"Frac…using 104.4 bbls 125 in 6% KCl w/10% methanol, 21 tons CO2...209 bbls 70Q & 60Q CO2 foam. Flush w/38 bbls 6% KCl water w/10 % methanol"	
	829.1	WR	2/21/2001		9.65	3.0		6.34		X		0			"Breakdown perfs w/6% KCL, 35 bbls…start ball sealers. Pump …48 bbls 6% KCL…Flush w/17 bbls 6% KCl…No gas."	
13-12	661.4	WR	6/1/2001		11.64	21.7	12.27	8.41		X		8,504	0	221	"Frac…using 87.9 bbls wf 125 in 6% KCl water w/10% methanol, 21 tons CO2...170 bbls 70Q & 60 Q CO2 foam. Flush w/33 bbls 6% KCl water w/10% methanol"	Yes

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (Mpa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
	706.2	WR	6/1/2001		10.92	26.4	18.96	7.27		X		14,989			"Frac…using 135.2 bbls wf 125 in 6% KCl water w/10% methanol, 35 tons CO2...323 bbls 70Q & 60Q CO2 foam. Flush w/36 bbls 6% KCl water w/10% methanol"	
	755	WR	6/1/2001		13.72	17.9	19.22	9.50		X		5,377			"Frac…using 76.1 bbls wf 125 in 6% KCl water w/10% methanol, 14 tons CO2...118 bbls 70Q & 60Q CO2 foam. Flush w/38.5 bbls 6% KCl water w/10% methanol"	
	841.6	WR	6/1/2001		16.89	26.3	17.58	7.87		X		12,313			"Frac…using 125.4 bbls wf 125 in 6% KCl water w/10% methanol, 24 tons CO2...258 bbls 70Q & 60Q CO2 foam. Flsuh w/43 bbls 6% KCl water w/10% methanol"	
	878.7	WR	6/1/2001		14.15	20.8	18.13	10.07		X		8,335			"Frac…using 102.6 bbls wf 125 in 6% KCl water w/10% methanol, 21 tons CO2...180 bbls 70Q & 60Q CO2 foam. Flush w/45 bbls 6% KCl water w/10% methanol"	
	905.6	WR	5/31/2001		17.33	23.4	17.58	10.10		X		14,715			"Frac…using 145.4 bbls wf 125 in 6% KCl water w/10% methanol, 35 tons CO2...320 bbls 70Q & 60Q CO2 foam. Flush w/46.5 bbls 6% KCl water w/10% methanol"	
34-11		WR											2	1,227	Producing from Wind River Formation with 9 perforated intervals. Information on stimulation missing from well completion report.	No
13-1		WR											0	309	Produced in Wind River Formation (7 perforated intervals). Information on stimulation missing from well completion report.	No
11-12	571.8	WR	8/3/2001		12.07	25.0				X		9,245	0	63	"Frac...70Q CO2 foam...68 bbls KCl, 113 bbls CO2"	No
	655.9	WR	8/3/2001		12.07	25.0		7.45		X		10,175			"Frac...70Q CO2 foam...87 bbls KCl, 117 bbls CO2"	
	689.5	WR	8/2/2001		10.72	25.0		7.13		X		11,837			"Frac-pump 70Q CO2 foam…88 bbls KCl, 152 bbls CO2"	
	785.2	WR	8/2/2001		16.24	30.0		8.87		X		15,515			"Frac-pump 70Q CO2 foam...121 bbls KCl, 183 bbls CO2"	
	922.9	WR	8/1/2001		17.24			9.13		X		8,233			"Frac-pump 70Q foam...92 bbls KCl, 99 bbls CO2"	
21-10	1350	FU	8/8/2001	27.58	24.13	30.0		9.10		X		14,893	6	9,066	"Frac-Breakdown w/8 bbls KCl…Pumped 70Q CO2 foam frac using...145 bbls KCl, 228 bbls CO2"	No
	1394	FU	8/8/2001	23.44	25.86	32.0		6.88		X		23,970			"Frac-Breakdown w/4 bbls KCl…Pumped 70Q CO2 foam frac using...226 bbls KCl, 316 bbls CO2".	
	1447	FU	8/8/2001	7.54	17.93	30.0		2.59		X		10,971			"Frac-Breakdown w/3 bls KCl…Pumped 70Q CO2 foam frac uisng...144 bbls KCl, 139 bbls CO2"	
	1471	FU	8/8/2001	20.45	26.20	35.0		3.48		X		13,757			"Frac-Breakdown w/60 bbls KCl…Pump with 70Q CO2 foam frac using...162 bbls KCl, 172 bls CO2"	
	1539	FU	6/1/2001	19.04						X		6,832			"Frac-Breakdown w/29 bbls 6% KCl…Pumped 70Q CO2 frac using...141 bbls KCl, 146 bbls CO2"	
	1570	FU	7/31/2001	18.37						X		9,596			"Frac-Breakdown w/12 bbls 6% KCl…Pumped 70Q CO2 foam frac using 74 bbls 6% KCl...126 bbls CO2…screened out w/6 bbls of the 4 PPA & 32 bbls of 6 PPA left in csg. Pumped 70.4 bbls 6% KCl & screened out again".	
	1666	FU	7/31/2001	10.58						X		20,160			"Frac-Breakdown w/16 bbls 6% KCl... Pumped 70Q CO2 foam using 204 bbls 6% KCl...242 bbls CO2"	
	1743	FU	7/26/2001	8.96				3.45		X		0			"Pump 10 bbls 8% KCl into formation"	
43-1	622.7	WR	9/1/2001	11.72	13.84	20.2		7.58		X		6,976	12	8,500	"Frac…using 69.2 bbls WF 125 in 6% KCl water, 15 tons CO2...147 bbls 70Q and 60Q CO2 foam. Flush w/31 bbls 6% KCL water"	No
	662.6	WR	9/1/2001		12.87	19.8		7.33		X		8,264			"Frac…using 79.4 bbls WF 125 in 6% KCl water, 20 tons CO2...174 bbls 70Q and 60Q CO2 foam. Flush w/33.5 bbls 6% KCL water"	
	689.2	WR	8/31/2001		14.21	24.2		7.28		X		9,508			"Frac…using 89.1 bbls WF 125 in 6% KCl water, 23 tons CO2...222 bbls 70Q and 60Q CO2 foam. Flush w/35 bbls 6% KCL water"	
	760.8	WR	8/31/2001	8.96	17.21	27.7		8.69		X		16,480			"Frac…using 124.8 bbls WF 125 in 6% KCl water, 41 tons CO2...357 bbls 70Q and 60Q CO2 foam. Flush w/39 bbls 6% KCL water"	
	885.7	WR	8/29/2001	13.65	15.32	24.4		11.45		X		14,427			"Frac…using 112.1 bbls WF 125 in 6% KCl water, 32 tons CO2...289 bbls 70Q and 60Q CO2 foam. Flush w/45 bbls 6% KCL water"	
33-1													0	3,176	Producing in Wind River Formation (10 perforated intervals). Information on stimulaton missing from well completion report.	No

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (Mpa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
12-7													0	118	Producing in Wind River Formation (6 perforated intervals). Information on stimulation missing from well completion report.	No
21-10W	585.5	WR	9/15/2001		18.02	19.1		8.80		X	16,245	0		21,102	"Frac…using 108.6 bbls YF 125 LG in 6% kcl wtr, 30 tons CO2...287 bbls 70Q & 60Q CO2 foam. Flush w/28 bbls 50/50 6% kcl wtr & CO2".	No
	645.9	WR	9/15/2001		15.44	28.0		8.62		X	12,674				"Frac…using 101.4 bbls YF 125 LG in 6% kcl wtr, 22 tons CO2...241 bbls 70Q & 60Q CO2 foam. Flush w/32 bbls 6% kcl wtr."	
	760.8	WR	9/15/2001		16.24	26.9		7.67		X	18,493				"Frac…using 139.5 bbls YF 125 LG in 6% kcl wtr, 38 tons CO2...342 bbls 70Q & 60Q CO2 foam. Flush w/38 bbls 6% kcl wtr".	
	850.1	WR	9/15/2001		10.64	21.2		7.29		X	7,439				"Frac…using 91.9 bbls wf 125 in 6% KCl wtr, 22 tons CO2...176 bbls 70Q & 60Q foam. Flush w/42.3 bbls 6% kcl wtr"	
	914.4	WR	9/14/2001		20.39	12.4				X	8,900				"Frac…using 88.5 bbls wf 125 in 6% KCl wtr, 20 tons CO2...166 bbls 70Q & 60 Q foam. Flush w/43 bbls 6% KCl water"	
	1062	FU	9/14/2001		16.80	25.8		9.45		X	14,369				"Frac...132.4 bbls wf 125 in 6% kcl wtr, 36 tons CO2...289 bbls 70Q & 60Q foam. Flush w/53 bbls 6% kcl wtr"	
	1134	FU	9/14/2001		14.53	30.9		5.45		X	28,038				"Frac…using 214.9 bblswf 125 in 6% kcl wtr, 72 tons CO2...615 bbls 70Q & 60Q foam. Flush w/57 bbls 6% kcl wtr"	
	1291	FU	9/14/2001		17.11	27.6		7.98		X	21,811				"Frac…uisng 184.3 bbls wf 125 in 6% kcl wtr, 59 tons CO2...536 bbls 70Q & 60Q CO2 foam. Flush w/65 bbls 6% kcl wtr."	
23-12	527.3	WR	9/19/2001 11.48		17.93	35.0		7.45		X	17,037	0		139	"totals pumped 112 bbls KCl, 218 bbls CO2"	Yes
	679.1	WR	9/19/2001 17.17		15.51	30.0		8.83		X	15,072				"totals pumped 118 bbls KCl, 180 bbls CO2"	
	712.6	WR	9/19/2001 16.89		15.17	25.0		8.07		X	7,459				"totals pumped 78 bbls KCl, 83 bbls CO2"	
	878.1	WR	9/19/2001 13.51		20.68	26.0		8.68		X	11,050				"totals pumped 106 bbls KCl, 134 bbls CO2"	
	1009	WR	9/19/2001 20.12		17.24	30.0		0.00		X	11,016				"totals pumped 111 bbls KCl, 134.6 bbls CO2"	
44-2	609	WR	9/21/2001 18.85		13.04	20.9		8.20		X	7,042	0		198	"Totals pumped 58 KCl, 88 CO2"	No
	648	WR	9/21/2001 15.51		10.63	25.3		6.76		X	14,223				"Totals pumped 107 KCl, 162 CO2"	
	753.5	WR	9/21/2001 24.82		11.91	27.0		6.89		X	15,162				"Totals pumped 119 bbls KCl, 180 CO2"	
	783	WR	9/21/2001 21.57		17.20	28.3		8.00		X	23,336				"Totals pumped 164 bbls KCl, 272 CO2"	
	921.7	WR	9/21/2001 22.75		13.93	22.0		8.62		X	8,091				"Frac-pumped WF 125 70Q…Loar XO2 pump…went to flush early to prevent screen out. Totals pumped 105 bbls KCl, 116 bbls CO2"	
	1132	FU	9/20/2001 21.68		19.31	34.0		6.55		X	13,180				"Frac-pumped WF 125 70Q…Totals pumped 131 bbls KCl, 152 bbls CO2"	
31-9	705	WR	10/18/2001	26.10	13.44	23.0		10.55		X	7,382	2		1,346	"66 bbl clean fluid, 92.4 bbls CO2. 422 bbl total load"	Yes
	802.2	WR	10/18/2001		15.31	26.0		9.33		X	11,660				"92 bbls clean fluid, 150.7 bbl CO2"	
	829.7	WR	10/18/2001	28.19	14.51	22.7		9.86		X	6,924				"82 bbls clean fluid, 81.6 bbl CO2"	
	892.1	WR	10/18/2001	24.71	13.29	23.0		12.09		X	7,022				"Total clean fluid 95 bbls, 108.1 bbls CO2"	
	1008	WR	10/18/2001	17.11	15.81	20.0		26.09		X	7,154				"Total clean fluid 87 bbls and 89.4 bbl CO2"	
34-10	1407	FU	10/6/2001 19.51		20.12	28.4	28.91	8.38		X	17,553	5		4,816	"Total pumped 143 bbls KCl, 219 bbls CO2"	Yes
	1447	FU	10/5/2001 20.20		16.15	18.9	26.89	19.10		X	8,437				"Total pumped 120 bbls KCl,167 bbls CO2"	
	1538	FU	10/4/2001 25.51		19.44	28.4	26.45	9.16		X	13,738				"Total pumped 136 bbls KCl, 206 bbls CO2"	
	1590	FU	10/3/2001 15.03		19.65	27.4	19.71	9.65		X	16,320				"Total pumped 156 bbls KCl, 242 bbls CO2"	
	1639	FU	10/2/2001 14.48		21.02	33.0	21.02	6.39		X	16,035				"Total pumped 145 bbls KCl, 230 bbls CO2"	
	1682	FU	9/26/2001 10.64		16.97	2.0	16.97			X	8,440				"Screened out with 8458# in 12/20 sand in csg…Total pump 83.6 KCl,108 bbls CO2"	
34-1	564.8	WR	10/11/2001	12.37	10.51	21.0	13.13	7.45		X	8,145	0		930	"Total pumped 82 bbls KCl, 95 bbls CO2"	No

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	682.8	WR	10/11/2001	10.26	14.82	30.0	16.10	7.96		X		10,866			"Total pumped 93 bbls KCl, 127 bbls CO2"	
	785.2	WR	10/11/2001	11.89	13.79	30.0	15.51	7.03		X		10,864			"Totals pumped 98 bbls KCl, 124 bbls CO2"	
	947.3	WR	10/11/2001	15.58	11.72	25.0	13.70	8.48		X		7,584			"Frac-WF 125 70Q…Totals pumped 92 bbls KCl, 87 bbls CO2"	
21-12	506	WR	10/27/2001	7.58	18.96	35.0	24.82	5.86		X		18,001	0	14	"Totals pumped 112 bbls KCl, 223 bbls CO2"	No
	563.3	WR	10/27/2001	22.93	18.96	35	23.79	7.70		X		15,142			"Totals pumped 107 bbls KCl, 180 bbls CO2".	
	823.9	WR	10/26/2001	12.74	14.13	25	26.20	6.89		X		7,232			"Totals pumped 67 bbls KCl, 104 bbls CO2"	
	963.8	WR	10/28/2001	19.99	20.68	27	25.51	11.20		X		11,377			"Totals pumped 105 bbls KCl, 134 bbls CO2"	
12-10	726.6	WR	10/26/2001	7.58	17.24	35.0	18.62	9.09		X		13,778	2	1,465	"Totals pumped 102 bbls K CL, 196 bbls CO2"	No
	790	WR	10/25/2001	14.48	17.93	25.0	27.21			X		7,244			"Frac-WF 125 70Q CO2 foam frac…screened out w/6032#...Totals pumbed 53 bbls 6% KCl, 86 bbls CO2"	
12-1	606.6	WR	11/10/2001	18.24	13.79	25.0		9.10		X		9,066	0	653	"Totals pumped 70 bbls KCl, 111 bbls CO2"	No
	704.7	WR	11/10/2001		12.76	30.0		6.34		X		10,465			"Totals pumped 99 bbls KCl, 131 bbls CO2"	
	929.9	WR	11/9/2001	21.05	21.72	28.0		9.40		X		10,928			"Totals pumped 88 bbls KCl, 153 bbls CO2"	
	1024	WR	11/9/2001	19.82	19.99	25.0		13.51		X		7,448			"Totals pumped 93 bbls KCl, 83 bbls CO2"	
42-3	438.9	WR	1/29/2005	12.69				7.43	27.14	X		6,978	0	1,675	"Frac w/64 bbls slickwater"	No
	507.8	WR	1/29/2005	11.36				6.92	23.75	X		6,812			"Frac w/100 bbls slickwater"	
	687	WR	1/26/2005	14.34				7.51	21.04	X		6,573			"Frac w/93 bbls slickwater"	
	727.6	WR	11/14/2001					9.14		X		8,718			"Frac w/68 bbls KCl, 103 bbls CO2"	
	774.8	WR	11/13/2001					12.20		X		7,944			"Frac w/67 bbls KCl, 110 bbls CO2"	
	850.4	WR	11/8/2001					9.51		X		12,775			"Frac w/95 bbls KCl, 163 bbls CO2"	
	1109	FU	11/2/2001					17.53		X		7,127			"Frac w/72 bbls KCl, 110 bbls CO2"	
22-1	626.7	WR	11/1/2001							X		6,898	0	892	"Frac w/168 bbl 75Q CO2 foam"	No
	687.6	WR	11/1/2001							X		10,005			"Frac w/197 bbl 75Q CO2 foam"	
33-10W	1064	FU	12/1/2001	24.13				12.34		X		9,929	2	8,228	"Frac-BD w/6% KCl...Pmp 230 bbl 70Q WF-125 CO2 foam...Total fluid 104, CO2 tons. Stimulation report indicates that 70Q CO2 WF-125 foam and fluids used contained Biocide B69, Surfactant EZEFLO F103, Foaming Agent F104, Breaker J218, Breaker Aid Liquid J318, Slurry PSG Polymer J877, Clay Stabilizer L55.	Yes
	1146	FU	11/30/2001					4.30		X		12,623			"Start 70Q CO2, 310 bbl"	
	1170	FU	12/10/2004							0					"Breakdown w Linear gel"	
	1191	FU	12/9/2004							0					"Breakdown w Linear gel"	
	1368	FU	11/16/2001	7.93	21.03	30.0		10.96		X		11,337			"Total pumped 113 bbls KCl, 163 bbls CO2"	
	1415	FU	11/15/2001	22.30	21.37	35.0		9.65		X		20,560			"Total pumped 172 bbls KCl, 229 bbls CO2"	
	1510	FU	11/14/2001	21.55	21.93			9.65		X		11,924			"Total pumped 154 bbls KCl, 154 bbls CO2"	
41-3	402.9	WR	2/2/2005	11.16				4.27	20.36	X		6,285	0	29	"Frac w/77 bbl slickwater"	No
	534.9	WR	12/6/2001	19.39	14.48	25.0		8.48		X		5,126			"Frac-BD w/6% KCl…Start 70Q CO2 143 bbls...75 bbls water, 14 ton CO2"	
	571.2	WR	2/1/2005	25.07				7.52	23.30	X		6,905			"Frac w/86 bbl slickwater"	
	595	WR	1/28/2005	26.10				8.79	25.11	X		6,657			"Frac w/93 bbl slickwater"	
	613.9	WR	1/26/2005	17.29				8.55	23.98	X		7,799			"Frac w/108 bbl slickwater"	
	731.8	WR	1/22/2005	28.28				10.74	24.88	X		8,196			"Frac w/104 bbl slickwater"	
	801.6	WR	12/5/2001	27.85	17.93	25.0		10.55		X		8,657			"Frac-BD w/6% KCl…Start 70Q CO2 170 bbl...22 ton CO2."	
	851	WR	12/5/2001	18.53	20.68	30.0		8.72		X		9,571			"Frac-BD w/6% KCl…Start 70Q CO2 211 bbls...109 bbl fluid & 20 ton CO2"	
	1065	FU	12/4/2001	25.86	20.68	30.0		10.82		X		8,008			"Frac-BD w/6% KCl…Pump 233 70Q CO2 foam...24 ton CO2, 129 bbl fluid."	

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (Mpa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
	1120	FU	11/29/2001	19.99	19.65	30.0				X		5,139			"Frac-Breakdown 29 bbl 6% KCl…Start 70Q CO2 foam 162 bbls…57 bbls fluid & 19 ton CO2…21 bbls flush screened out w/4410# 6# sand in formation."	
	1183	FU	11/27/2001		18.27	30.0		10.55		X		11,141			"Frac w/6% KCl…Start 70Q CO2 foam, 235 bbls slurry…flush 57 bbl 50Q foam…32 ton CO2, 140 bbl 6% KCl."	
22-11	568.1	WR	12/15/2001	12.83	12.07	30.0		7.38		X		9,885	0	306	"Frac-Start 75Q foam…pump 197 bbls foam…25 tons CO2, 67 bbls fluid"	No
	690.1	WR	12/15/2001	20.20	13.79	35.0		6.83		X		12,391			"Frac-Breakdown w/6% KCl…Start 75Q CO2 foam 281 bbls, 31 tons CO2, 137 gel"	
	730.9	WR	12/14/2001	26.54	13.79	30.0		8.08		X		10,146			"Frac-Breakdown…Totals pumped 93 bbls KCl, 134 bbls CO2"	
	845.5	WR	12/14/2001	16.20		30.15		0.00		X		0			"Frac…psi increasded to 4373-bled well down, psi continued to climb to 4007 shut down job. Pumped 87 bbls KCl & 96 bls CO2"	
	905.6	WR	12/14/2001	24.15	22.06	33.0	23.44	10.59		X		8,303			"Frac…Totals pumped 146 bbls KCl, 149 bbls CO2"	
	951.6	WR	12/13/2001		18.62	25.0	29.58			X		5,645			"Frac-Pump 41 bbls KCl, 85.7 bbls CO2…Screened out w/3227# in formation, 9219# in csg"	
43-11	507.2	WR	1/4/2002	11.50	19.31	37.0		8.23		X			0	140	"Frac-Breakdown w/6%KCl…Start 75Q CO2, 411 bbls foam, 123 bbls fluid, 44 tons CO2"	No
	589.5	WR	1/4/2002	10.59	16.55	30.0		9.17		X		8,059			"Frac-Breakdown w/6% KCl…Start 75Q CO2, 202.5 bbls fluid, 20 ton CO2"	
	734.9	WR	1/4/2002	14.82	20.68	35.0		6.89		X		9,684			"Frac-Breakdown w/6% KCl…Start 75Q CO2, 243 bbls, 97 bbls fluid, 23 tons CO2"	
	766.9	WR	1/4/2002	1.31	21.37	35.0		8.80		X		12,222			"Frac-Breakdwon w/6% KCl…Start 75Q CO2 foam, 143 bbls fluid, 26 tons CO2"	
	1032	FU	1/3/2002	16.26	21.37	32.0		8.91		X		6,967			"Frac-Break down w/6% KCl…Start 70Q CO2 frac, 299 bbls, 136 fluid, 28 tons CO2"	
	1106	FU	12/19/2001	17.23	22.41	32.5		4.90		X		7,586			"Frac-Break down w/6% KCl…Start 70Q foam 306 bbls, 157 bbls gel, 25 tons CO2"	
	1160	FU	12/18/2001	16.10	19.99	38.0		5.91		X		27,318			"Frac-Break w/6% KCl…Start 70Q foam 881 bbls, 275 bbls gel, 97 tons CO2"	
11-3	702.9	WR	12/12/2001	26.89	15.86	25.0		7.45		X		5,648	1	1,895	"Frac-Break w/6% KCK…Start w/168 bbls 75Q CO2 foam, 17 ton CO2, 60 bbls of fluid"	No
	804.7	WR	12/12/2001	18.68	15.17	25.0		8.66		X		7,983			"Frac-Break w/6% KCl…Start w/180 bbls 75Q CO2, 19 ton CO2, 96 bbls wtr"	
	899.8	WR	12/12/2001	19.08	18.62	25.0		8.63		X		7,888			"Frac-Break w/6% KCl…Start w/169 bbls 75Q CO2 foam, 51 bbl gel, 19 ton CO2"	
	1167	FU	12/6/2001	29.30	24.13	27.0				X		7,121			"Frac-Break down w/6% KCL…Start 70Q CO2 185 bbls…20 tons CO2, 55 bbl gel…Screened out 4161 in formation, 11540 in pipe... Re-frac break w/6% KCl 50 bbls. Start 337 bbl 75Q foam, 36 ton CO2, 147 bbl fluid…screened out w/12331 in formation, 5867# in pipe"	
41-10	493.2	WR	1/20/2002	15.72	14.48	35.0		6.89		X		11,832	0	157	"Frac-Break w/6% KCL…Start 75Q CO2, 70 bbls fluid, 28 ton CO2…flush 24 bbls 50/50"	Yes
	661.7	WR	1/20/2002	19.27	13.79	35.0		7.86		X		11,104			"Frac-Break down w/6% KCL…Start 75Q foam, 96 bbls gel, 27 ton CO2...32 bbls 6% KCl flush"	
	766.9	WR	1/19/2002	17.65	14.48	30.0		8.48		X		9,525			"Frac-Break down w/6% KCL…Start 75Q 208 bbls, foam 63.5 bbls, 26 ton CO2…flush 37 bbls 50/50 flush"	
	789.1	WR	1/19/2002	11.89	15.86	35.0		7.14		X		11,118			"Frac-Break down w/6% KCL…Start 75Q foam 228 bbl, 64.5 fluid, 26 ton CO2…Flush w/40.5 bbls 6% KCl"	
	841.2	WR	1/29/2002	11.03	15.86	35.0		6.41		X		10,559			"Frac-Break down w/6% KCL…Start 75Q foam 222 bbls, 62.5 bbls fluid, 26 ton CO2... 43.5 bbls flush 6% KCl"	
	863.8	WR	1/19/2002	18.62	13.79	25.0		8.96		X		6,562			"Frac-Break w/6% KCL…Start 75Q foam 144 bbls, 44 bbls fluid, 16 ton CO2…flush 44.5 bbls 6%"	
	959.5	WR	1/19/2002	16.13	14.48	25.0				X		7,228			"Frac-Break down w/6% KCl…Start 75Q CO2 150 bbl fluid, 18 ton CO2…flush 48 bbls 6% KCl"	
13-12W	780.9	WR	1/23/2002	18.09	14.48	30.0				X		11,819	1	322	"Frac-Break down w/6% KCl…Start 75Q foam, 72 bbls fluid, 30 tons CO2... 37 bbl 50/50"	No
	823.6	WR	1/23/2002	15.49	14.48	30.0		9.10		X		6,214			"Frac-Break down w/6% KCl…Start 75Q CO2 foam, 175 bbls, 78 bbl fluid, 16 ton CO2"	
	982.4	WR	1/22/2002	19.05	18.62	25.0	29.33			X		6,456			"Break w/6% KCl…Start 75Q foam, 146 bbls, 43 bbl fluid, 17 tons CO2...screened out w/7900# in formation, 6340# in pipe"	
	1052	FU	1/22/2002	20.82	18.62	30.0		8.56		X		6,917			"Frac-Break w/6% KCl…Start 70Q foam 258 bbls, 81 bbl fluid, 24 ton CO2...52 bbl 6% flush"	
	1125	FU	1/22/2001	16.55	19.99	35.0		6.00		X		16,565			"Frac-Break w/6% KCl…Start 70Q CO2 foam, 482 bbls, 142 bbls fluid, 55 ton CO2…55 bbl flush 6% KCL"	

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Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (Mpa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
24-3B	1353	FU	2/6/2002	14.55	15.86	35.0		5.07		X		18,835	2	13,316	"Frac-Breakdown…start 70Q CO2 foam- 564 bbls, 169 bbls gel, 62 tons CO2…65 bbl flush 50/50…did not screen out…monitored well 24X-3 off set, psi did not increase"	No
	1401	FU	2/6/2002	25.51		27.58		7.36		X		17,156			"Frac-Breakdown…totals pumped 184 bbls KCl, 337 bbls CO2…CO2 hose leaking"	
	1464	FU	1/30/2002	11.72	21.72	35.0	23.24	6.17		X		15,161			"Frac…Breakdown…Totals pumped 161 bbls KCl, 297 bbls CO2"	
	1470	FU	1/30/2002	12.09	21.37	35.0	22.41	3.74		X		15,663			"Frac-Breakdown…Total pumped 207 bbls KCl, 282 bbls CO2"	
	1534	FU	1/29/2002	12.41	25.51	35.0	27.92	9.62		X		13,287			"Frac…Breakdown…total pumped 190 bbls KCl, 254 bbls CO2"	
11-11B	462.1	WR	2/18/2005	12.31		33.9	19.37	6.48		X		7,221	4	13,056	"Frac...18 ton of CO2, 63 bbl of clean fluid"	Yes
	524	WR	2/18/2005	12.79		33.9	20.29	10.32		X		6,550			"Frac...15 tons CO2 and 78 bbls clean fluid"	
	566.3	WR	2/18/2005	10.02		35.0	17.01	7.09		X		9,254			"Frac...23 ton CO2 and 95 bbls clean fluid"	
	659	WR	2/18/2005	26.23		35.6	21.13	7.04		X		8,315			"Frac...19 tons of CO2 and 91 bbls clean fluid"	
	688.8	WR	2/18/2005	9.96		36.3	17.84	7.56		X		11,269			"Frac…27 tons of CO2 and 124 bbls clean fluid"	
	965	BWR	2/17/2005	11.48		36.7	1.31	1.59		X		13,150			"Frac…32 ton of CO2, 232 bbls clean fluid"	
	1027	FU	2/14/2002	21.93	16.55	35.0				X		4,923			"Frac...Break w/6% KCl…Frac using 197 bbls 70Q CO2 foam, 64 bbls gel, 22 ton CO2... Flush w/6% KCl & 50/50 CO2"	
	1045	FU	2/15/20005	18.73				10.02		X		16,084			"Frac...211 bbl clean fluid and 42 ton CO2"	
	1078	FU	2/14/2002	9.17	18.62	35.0				X		10,778			"Frac-Break w/6% KCl…Frac uisng 386 bbl 70Q CO2 foam, 140.5 bbls gel, 37 tons CO2...53.5 bbls 6% flush"	
	1158	FU	2/13/2002	15.76	19.31	35.0				X		10,600			"Frac-Break w/6% KCl…Frac using 346 bbls 70Q CO2, 138 bbls gel, 33 tons CO2. Flush w/56 bbls 50/50 CO2"	
	1316	FU	2/12/2002	17.58	21.72	35.0				X		11,547			"Frac: Break w/6% KCl…Frac using 70Q CO2 foam, 157 bbls gel, 37 tons CO2... 64 bbl flush 50/50."	
	1375	FU	2/9/2002	19.62	19.31	35.0		7.61		X		15,569			"Frac: Break w/6% KCl…Frac w/438 bbls 70Q foam, 145 bbls gel, 50 tons CO2…flush 60% CO2."	
	1404	FU	2/12/2005	24.13				7.03		X		20,118			"Frac…pumped 356 bbl clean fluid…and 33 tons CO2"	
	1442	FU	2/9/2002	22.85	21.37	35.0				X		9,515			"Frac: Break w/6% KCl…Frac w/280 bbls 70Q CO2 foam, 83 bbls gel, 28 tons CO2"	
31-11	598.6	WR	2/19/2002	10.67	18.96	35.0		7.10		X		12,955	0	207	"Frac-BD w/6% KCl…Frac using 75Q foam, 63 bbls gel, 25 tons CO2...27 bbls 30Q foam flush"	No
	678.2	WR	2/20/2002	7.79	12.07	25.0		6.14		X		6,781			"Frac-BD w/6% KCl…Frac using 140 bbls 75Q foam, 41.5 bbls gel, 17 ton CO2…flush 32 bbls 6% KCl"	
	730	WR	2/19/2002	21.92	13.79	25.0		7.58		X		6,715			"Frac-BD w/6% KCl…Frac using 142 bbls 75Q CO2 foam, 41 bbls gel, 16 tons CO2...36 bbls 6% KCl"	
	774.5	WR	2/19/2002	13.65	17.93	30.0		8.20		X		9,167			"Frac-BD w/6% KCl…Frac using 75Q CO2 foam, 92 bbls gel, 23 ton CO2…flush w/38.5 bbls 6% KCl"	
	808.9	WR	2/16/2002	7.01	19.31	30.0		8.52		X		10,883			"Frac-BD w/6% KCl…Frac using 75Q foam, 63 bbls gel, 24 ton CO2…flush w/40 bbls 6%"	
	1034	FU	2/16/2002	16.75	25.51	35.0				X		12,244			"Frac-BD w/6% KCl…Frac uisng 75Q CO2, 123 bbls gel, 41 tons CO2	
	1109	FU	2/16/2002	20.93	18.62	35.0		4.96		X		11,494			"Frac-BD w/6% KCl…Frac using 380 bbls 70Q CO2 foam, 112 bbls gel, 45 ton CO2...54 bbls 6% KCl flush"	
	1139	FU	2/15/2002	15.03	9.65	22.0				X					"Frac-BD w/6% KCl…Frac using 85 bbls CO2, 25 bbls in formation"	
	1153	FU	2/15/2002	15.86	15.17	30.0				X					"Frac-BD w/6% KCL…Frac uisng 85 bbls 75Q CO2, flush 25 in formation…recover 17 bbls of 85 bbls"	
	1180	FU	2/14/2002	27.30	16.20	35.0		4.34		X		12,280			"Frac-BD w/6% KCl…Frac uisng 346 bbls 70Q CO2 foam, 104 bbls gel, 39 ton CO2…flush w/46 bbls 50/50 + 10 bbls 6% KCl…111 of 190 recovered"	
23-3	510.2	WR	2/21/2002	16.55	12.07	25.0		7.93		X		8,741	2	1,202	"Frac-BD w/6% KCl...Frac using 176 bbls 75Q CO2, 44 bbls gel, 20 ton CO2...23 bbls 6% KCl + CO2 flush"	No
	641.9	WR	2/21/2002		15.17	25.0		8.89		X		8,482			"Frac-BD w/6% KCl...Frac using 176 bbls 75Q CO2, 52 bbls gel, 20 ton CO2...30 bbls 6% flush"	
	775.4	WR	2/21/2002	11.65	19.31	32.0		7.58		X		11,113			"Frac-BD w/6% KCl...Frac using 75Q CO2, 109 bbls gel, 26 ton CO2...36.5 bbls 6% KCl flush"	
	823	WR	2/20/2002	22.41	15.17	27.0		9.89		X		9,843			"Frac-BD w/6% KCl...Frac using 75Q CO2, 64 bbls gel, 19 ton CO2...39 bbls 50/50 flush…made recover 122 bbls of 629"	
	844.9	WR	2/20/2002	12.03	15.86	27.0		10.17		X		10,985			"Frac-BD w/6% KCl...Frac using 75Q CO2, 65.5 bbls gel, 27 ton CO2...42.5 bbls 6% KCl flush"	

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	1055	FU	2/20/2002	20.77	18.27	30.0		9.17		X		6,668			"Frac-BD w/6% KCl...Frac using 206 bbls 70Q CO2, 65 bbls gel, 24 ton CO2...52 bbls 6% KCl flush"	
	1155	FU	2/20/2002	8.27	18.96	35.0		4.07		X		14,878			"Frac-BD w/6% KCl...Frac using 492 bbls 70Q CO2, 184 bbls gel, 50 ton CO2...56 bbls 6% KCl flush"	
	1372	FU	2/19/2002	15.38	16.89	35.0		5.38		X		14,945			"BD w/6% KCl...Frac using 70Q CO2, 144 bbls gel, 53 ton CO2...flush w/67 bbls 50% CO2"	
32-11	532.8	WR	2/26/2002	12.55	13.79	25.0		7.83		X		8,056	2	1,027	"Frac-BD w/6% KCl…Frac using 161 bbls 75Q CO2 foam, 45 bbls gel, 18 ton CO [CO2]…24 bbls KCl flush"	No
	603.2	WR	2/26/2002	17.45	15.86	30.0		5.52		X		9,764			"Frac-BD w/6% KCl…Frac using 201 bbls 75Q CO2, 56 bbls gel, 23 ton CO2...28.5 bbls 6% flush"	
	721.2	WR	2/26/2002	19.31	13.79	30		6.79		X		9,906			"Frac-BD w/6% KCl…Frac using 206 bbls 75Q CO2, 60 bbls gel, 23 tons CO2...34 bbls 8% flush"	
	747.1	WR	2/26/2002	13.15	20.68	35		6.21		X		12,079			"Frac-BD w/6% KCl…Frac uisng 273 bbls 70Q CO2, 110 bbls gel, 28 ton CO2…37.5 bbls 6% flush"	
	963.8	BWR	2/23/2002	15.44	12.07	35		3.35		X		13,816			"Frac-BD w/6% KCl…Frac using 296 bbls 75Q CO2, 87 gel, 35 ton CO2...46 bbls 50% CO2 flush"	
	1035	FU	2/22/2002	30.67	26.20	28				X		6,218			"Frac-BD w/6% KCl…Frac using 207 bbls 70Q CO2, 72 bbls gel, 22 tons CO2…screened out w/6570# in formation, 7136 in pipe…recover 122 of 609"	
	1102	FU	2/22/2002	20.34	18.96	35		5.52		X		12,428			"Frac-BD w/8% KCl…Frac using 382 bbls 70Q CO2, 121 bbls gel, 43 ton CO2...54 bbls 6% flush"	
	1133	FU	2/22/2002	26.20	17.24	33		4.69		X		17,565			"Frac-BD w/6% KCl…Frac using 70Q foam, 164 bbls gel, 59 ton CO2...57 bbls 6% flush"	
	1161	FU	2/21/2002	24.82	17.93	40.0		2.34		X					"Frac-BD w/6% KCl…Frac using 50 bbls 75Q foam, flush w/50Q foam…Total fluid 53 bbls, 12 ton CO2, flush 60 bls 50Q foam"	
44-11	536.4	WR	2/28/2002	19.55	13.79	25.0		6.62		X		7,248	2	1,643	"Frac-BD w/6% KCl…Frac using 150 bbls 75Q CO2 foam, 47 bbls gel, 16 tons CO2…Flush w/24.5 bbls 50% CO2"	No
	642.8	WR	2/28/2002	14.60	14.48	25.0				X		6,940			"Frac-BD w/6% KCl…Frac using 147 bbls 75Q CO2 foam, 44 bbls gel, 17 ton CO2….30 bbls 6% flush"	
	872.9	WR	2/28/2002	20.11	15.86	35.0		11.17		X		6,917			"Frac-BD w/6% KCl…Frac using 152 bbls 75Q CO2 faom [foam], 47 bbls gel, 17 ton CO2"	
	996.7	BWR	2/28/2002	19.17	19.17	35.0		1.52		X		13,653			"Frac-BD w/6% KCl…Frac using 303 bbls 75Q CO2 foam, 83 bbls gel, 35 ton CO2"	
	1109	FU	2/28/2002	29.65	13.10	30.0		5.17		X		8,255			"Frac-BD w/6% KCl…Frac using 245 bbls 70Q CO2 foam, 87.5 bbls gel, 28 ton CO2…flush w/54 bbls 6% KCl"	
	1172	FU	2/26/2002	13.13	20.68	34		6.96		X		21,469			"Frac-Breakdown w/6% KCl…Frac using 620 bbls 70Q CO2 foam, 182 bbls gel, 69 tons CO2…flush w/57 bbls 50% CO2"	
42-9W													5,051	25,303	Production in Wind River Formation. 8 perforated intervals from 1776-3138.' No information on stimulation	No
32-9W	779.7	WR	3/19/2002	17.42	18.27	32.0		6.83		X		13,420	2	1,380	"Frac-Break…Pump pad… 28+2 tons CO2, 132.6 load"	Yes
	832.1	WR	3/19/2002	17.24	13.10	25.0		8.76		X		7,487			"Frac-Break formation…Pump pad...17+1 CO2, 105 bbls load"	
	894.9	WR	3/19/2002	22.23	18.62	30.0		10.34		X		9,784			"Frac-Break formation…Pump pad...128 bbls load, 22+1 tons CO2"	
	1001	WR	3/19/2002	23.92	26.89	28.0		10.55		X		9,502			"Frac-Break formation…Pump pad...103.6 bbls clean fluid, 22+2 tons CO2"	
32-10B	1378	FU	3/22/2002	10.62	19.31	35.0				X		27,373	14	4,727	"Frac-Break.. CO2 hose ruptured during pad/replace. Extend pad 53 bbls…97 tons CO2…296.4 bbls"	Yes
	1442	FU	3/33/2002	12.41	19.31	35.0		3.45		X		19,395			"Frac-fill hole 57 bbls, break…Frac using 62 tons CO2…275 bbls"	
	1476	FU	3/21/2002	18.13	26.54	34.0		3.79		X		18,277			"Frac-Break formation…Frac using…67 tons CO2, 198 bbls load"	
	1569	FU	3/21/2002	13.79	26.89	28.0		10.14		X		18,286			"Frac-Break…Frac using…63 tons CO2, 314 bbls load"	
	1614	FU	3/20/2002	17.25	22.06	35.0		6.69		X		14,080			"Frac-Break…Frac using…50+2 ton CO2, 318 bbls kcl"	
	1663	FU	3/20/2002	18.96	25.51	32.0		3.52		X		17,780			"Frac-Break…Frac-pump pad…56+2 ton CO2, 234 kcl"	
	1716	FU	3/20/2002	17.93	24.13	30.0		14.65		X		7,167			"Frac-Break formation…Frac using …204 bbls 6% kcl, 23+2 tons CO2"	
13-11B	1102	FU	4/6/2002		19.65	35.0				X		14,787	0	7,087	"Frac-Breakdown w/6% KCl…Frac using 70Q CO2 foam, 125 bbls gel, 39 tons CO2...53 bbls 50% CO2 flush"	No
	1145	FU	4/6/2002	11.72	24.13	42.0		5.07		X		30,552			"Frac-Break w/6% kcl…Frac using 70Q CO2, 896 bls, 283 bbls gel, 97 ton CO2…57 bbls 30% CO2 flush"	
	1385	FU	3/23/2002	10.58				6.83		X		19,758			"Frac-Break…67 tons CO2+209 bbls load"67 tons CO2, 209 bbls "load"	

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Avgerage Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (Mpa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
	1452	FU	3/23/2002		20.68	35.0		8.27		X		10,851			"Frac-Break formation…167 bbls, 34 tons CO2"167 bbls of ?, 34 tons CO2	
	1572	FU	3/23/2002		16.55	35.0		10.48		X		9,568			"Frac-Break formation…35 ton CO2 & 175 bbls fluid"35 tons CO2, 175 bbls "fluid"	
14-3W	1359	FU	4/9/2002	8.19	22.75	37.0				X		23,224	3	5,695	"Frac-Break down w/6% KCl…Frac using 70Q CO2. 650 bbls, 183 bbls gel, 70 tons CO2...86 bbls 50% CO2 flush"	Yes
	1408	FU	4/9/2002	7.83	22.75	36.0		4.48		X		22,290			"Breakdown w/6% KCl...Frac using 70Q CO2 foam 630 bbls, 174 bbls gel, 71 ton CO2...72 bbls 6% flush"	
	1538	FU	4/9/2002	14.20	22.75	33.0		7.58		X		11,857			"Break down w/6% KCl...Frac using 70Q CO2 faom [foam], 338 bbls, 39 ton CO2…76 bbls 6% flush"	
	1578	FU	4/6/2002	15.86	26.20	27.0				X		7,145			"Break down w/6% KCl...Frac using 70Q CO2 209 bbls, 22 ton CO2…screened out w/12411# in formation, 3342# in pipe"	
	1608	FU	4/5/2002	17.13	27.58	27.0				X		7,108			"Break down w/6% KCl...Frac using 206 bbls gel, 20 ton CO2"	
12-2	683.4	WR	11/29/2001	15.51				9.79		X		8,763	0	0	"BD w/6% KCl…171 bbls 70Q CO2…54 bbls 6% KCL, 22 ton CO2, 32 bbls 50Q foam"	No
	851	WR	11/29/2001	21.51	15.17	25.0		9.24		X		7,385			"Frac BD w/6% KCl…start 70Q CO2 foam 177 bbls...41.5 bbls KCl flush"	
	941.2	WR	11/29/2001	28.96	14.82			9.97		X		8,432			"Frac-BD w/6% KCl…Start 70Q CO2 foam. 174 bbls...81 bbls 6% KCl, 22 ton CO2. Flush w/45 bbls 50Q CO2"	
	1066	FU	11/27/2001	27.58						X		7,879			"Break w/6% KCl…Start 70Q CO2 foam, 164 bbls slurry pumped…17370# 12/20 sand screened out w/11278# in pipe, 6083# in formation. Total 51 bbls no flush pumped"	
23-10W	651.1	WR	12/14/2002	21.50	24.13	32.0		10.98		X		15,987	2	5,892	"Frac-Pumped 114 bbls KCl, 219 bbls CO2"	No
	793.1	WR	12/14/2002	26.24	17.93	35.0		10.62		X		17,251			"Frac-Pumped 136 bbls KCl, 220 bbls CO2"	
	881.8	WR	12/14/2002	23.12	16.89	25.0				X		6,130			"Frac-Pumped 111 bbls KCl, 138 bbls CO2"	
	1138	FU	12/13/2002	12.94	16.55	30.0		7.27		X		7,644			"Frac-Pumped 105 bbls KCl, 178 bbls CO2"	
	1161	FU	12/13/2002	7.64	20.68	35.0		4.14		X		23,873			"Frac-Pumped 258 bbls KCL, 442 bls CO2"	
	1310	FU	12/12/2002	16.33	22.41	35.0		9.65		X		14,436			"Frac-Pumped 192 bbls KCl, 260 bbls CO2"	
23-10C	539.8	WR	10/13/2004							X		7,741	6	4,554	"Flush w/22 bbls. Screen out w/2 bbls let on flush"	Yes
	557.2	WR	10/13/2004	7.36				7.62		X		6,705			"Flush w/28 bbls water"	
	701	WR	10/13/2004	13.10				7.79		X		10,550			"Flush w/34 bbls water"	
	730.9	WR	10/13/2004	8.57				7.43		X		7,928			"Flush w/36 bbls"	
	812	WR	10/13/2004	14.94						X		6,895			"Start flush 20 bbls"	
	864.1	WR	10/13/2004	11.38				7.45		X		8,342			"Flush w/43.5 bbls water"	
	927.5	WR	10/13/2004	18.34				7.98		X		6,581			"Flush to top perf w/46 bbls water"	
	949.8	WR	10/13/2004	9.17				7.58		X		7,032			"Flush to top perf w/48 bbls water"	
	1077	FU	10/4/2004	10.74						X		0			"Start frac when 26 bbls flush away"	
	1143	FU	10/4/2004	7.58	15.51	35.0		6.21		X		9,295			"131 bbl clean fluid and 30 ton CO2"	
	1411	FU	10/4/2004		15.17	35.0		6.48		X		9,388			"28 ton CO2"	
	1544	FU	10/4/2004	10.30	22.06	35.0		7.14		X		7,711			"166 bbl "clean fluid", 24 ton CO2"	
	1594	FU	10/4/2004	8.73	16.55	35.0		5.81		X		10,216			"182 bbl clean fluid and 28 ton CO2"	
	1646	FU	10/4/2004	8.73	22.06	35.0		6.71		X		13,017			"225 bbl "clean fluid" and 39 tons CO2"	
	1690	FU	10/4/2004	11.88	24.13	35.0		6.71		X		12,987			"268 bbl "clean fluid" and 39 tons CO2"	
34-3B	951.3	WR	4/19/2005	15.86		19.24		7.24		X		7,511	2	9,501	"Frac 139 bbls slickwater"	No
	1039	FU	11/9/2004							X		13,608			"Frac w/70Q CO2 foam."	
	1070	FU	11/9/2004							X		13,608			"Frac w/70Q CO2 foam"	
	1134	FU	11/9/2004							X		9,525			"Frac w/0Q CO2 foam"	
	1401	FU	11/9/2004							X		13,608			"Frac w70Q CO2 foam"	

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	1490	FU	11/9/2004			34.47				X	10,886				"Frac w/70Q CO2 foam…screened out w/7 bbls flush remaining…pressure up to 5000# could not pump into perfs"	
	1522	FU	11/2/2004	16.13	22.75	35.0				X	7,705				"Frac…185 bbl clean fluid, 29 tons CO2. Screened out 46 bbl into flush"	
	1555	FU	11/2/2004	13.49	19.31	35.0		9.17		X	10,475				"Frac…185 bbl clean fluid, 33 ton CO2"	
	1579	FU	11/2/2004	14.34	22.06	35.0		8.05		X	17,271				"Frac…267 bbl clean fluid, 49 tons CO2"	
	1604	FU	11/2/2004	10.34	26.20	35.0		16.82		X	20,026				"Frac…32 bbl clear fluid, 49 ton CO2"	
24-2	468.8	WR	10/27/2004	7.07	14.48	35.0		6.06		X	7,018	0		174	"Frac...86 bbl clean fluid, 26 tons CO2, flush w/50 quality."	No
	497.1	WR	10/27/2004	4.83	10.34	35.0		4.65		X	9,602				"frac...118 bbl clean fluid, 29 tons CO2"	
	699.2	WR	10/27/2004	11.48	14.48	35.0		6.07		X	9,696				"Frac…29 tons CO2, 128 bbl clean fluid"	
	796.7	WR	10/27/2004	8.48	16.55	35.0		6.55		X	6,275				"Frac…108 bbl clean fluid, 18 tons CO2"	
	1116	FU	10/27/2004	14.80	19.31	35.0		7.24		X	10,854				"Frac…170 bbls clean fluid, 31 tons CO2"	
	1154	FU	10/29/2004	2.07	17.24	35.0		4.14		X	11,528				"Frac…246 bbl clean fluid, 34 tons CO2"	
	1172	FU	10/26/2004	10.34	20.68	35.0		3.65		X	16,140				Frac...227 bbl clean fluid, 49 tons CO2"	
23-10B	698	WR	10/21/2004	10.41	18.62	35.0		6.93		X	6,485	6		4,625 "92	bbl clean fluid, 22 ton CO2"	Yes
	819.6	WR	10/21/2004	8.96	17.93	35.0		8.00	19.91	X	6,473				"150 bbl clean fluid, 20 tons CO2	
	872.6	WR	10/20/2004	8.30	19.65	35.0		7.35	18.55	X	6,559				"96.5 bbls clean fluid, 22 tons CO2. Flush w/50Q"	
	893.7	WR	10/20/2004	12.45	19.99	35.0		9.86	21.49	X	6,628				"117 bbls clean fluid, 19 tons CO2"	
	934.8	WR	10/20/2004	11.71	17.24	35.0		8.83	19.68	X	9,181				"141 bbls clean fluid, 28 tons CO2"	
	1082	FU	10/20/2004	14.78	19.31	35.0		10.29	19.68	X	9,174				"149 bbls clean fluid, 28 tons CO2"	
	1134	FU	10/20/2004	8.94	18.62	35.0		7.58	16.29	X	10,310				"224 bbls clean fluid, 34 tons CO2"	
	1395	FU	10/16/2004	10.34	15.86	35.0		3.00		X	18,086				"235 bbls clean fluid, 54 tons CO2"	
	1458	FU	10/16/2004	11.20	17.24	35.0		3.19		X	15,481				"248 bbls clean fluid, 43 tons CO2"	
	1631	FU	10/16/2004	13.71	20.68	35.0		4.92		X	15,804				"267 bbls clean fluid, 43 tons CO2"	
	1669	FU	10/16/2004	10.38	21.37	35.0		1.21		X	15,989				"224 bbl clean fluid, 43 ton CO2"	
33-10B	500.5	WR	12/6/2004	7.78				9.09		X	9,0	72 2		2,219 "Sli	ckwater, CO2 assist-96 bbl"	Yes
	523.3	WR	12/6/2004	30.59				8.30		X	8,165				"Slickwater, CO2 assist-83 bbl"	
	582.2	WR	12/6/2004	11.02				9.14		X	10,433				"Slickwater, CO2 assist-89 bbl"	
	704.1	WR	12/6/2004	27.02				7.50		X	6,804				"Slickwater, CO2 assist-87 bbl"	
	728.2	WR	12/6/2004	16.15				14.63		X	5,897				"Slickwater, CO2 assist-85 bbls"	
	808.9	WR	12/6/2004	12.79				8.46		X	14,515				"Slickwater, CO2 assist-140 bbl"	
	865	WR	12/5/2004	18.37				9.47		X	6,123				"Slickwater, CO2 assist-89 bbl"	
	960.1	WR	12/5/2004	17.96				12.04		X	6,804				"slickwater, CO2 assist-180 bbl"	
	1074	FU	12/5/2004	17.37				8.96		X	15,966				"Slickwater, CO2 assit-177 bbl"	
	1170	FU	12/5/2004	4.32				8.25		X	15,876				"Slickwater, CO2 assit-187 bbl"	
	1406	FU	12/5/2004	10.96				6.78		X	16,329				"Slickwater, CO2 assist-260 bbl"	
	1453	FU	11/23/2004	15.71				3.01		X	6,877				"Slickwater, CO2 assit-102 bbl"	
	1535	FU	11/23/2004	26.32				12.69		X	10,048				"Slickwater, CO2 assit-126 bbl"	
12-11B	428.5	WR	12/31/2004	10.73	10.14	13.21		6.54		X	13,387	0		731	No description of stimulation fluids in well completion report. From WOGCC (2014), "Wind River Sands were selectively perforated between 1,406' and 2,674' and fracture treated with an estimated total of 610 barrels of CO2 assisted gelled water...The shallowest perforations are 1,406'-1,473' and this interval was fracture treated with 110 barrels of CO2 assisted gelled water"	Yes
	467.6	WR	12/31/2004	13.47	9.68	14.23		5.98	22.85	X	7,251				see above	

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	499.9	WR	12/31/2004	10.71	10.17	14.04		5.80	21.72	X	7,910				see above	
	523	WR	12/31/2004	17.20	12.82	17.20		5.81	21.26	X	7,909				see above	
	811.7	WR	12/31/2004	8.61	11.24	16.77		5.37	16.74	X	8,147				see above	
	1050	FU	12/31/2004	9.54	12.70	19.54		6.40	16.29	X	11,320				From WOGCC (2014) "fracture treated with an estimated 100 barrels of CO2 assisted gelled water"	
43-10B	551.7	WR	11/18/2004	11.09	11.14	21.3	16.63	8.69	25.79	X	6,666	2		2,606	From stimulation rpt: 3529 gal wa ter, 3529 gal 70Q CO2 WF12, 43 lb J218. 25 lb/1000 gal polymer loading.	Yes
	577.6	WR	11/18/2004	22.13	18.16	21.0	24.12	9.45	26.47	X	6,817				From stimulation rpt: 4206 gal water, 2989 gal 70Q CO2 WF12, 44 lb J218. 25 lb/1000 gal polymer loading.	
	638.3	WR	11/18/2004	10.69	12.60	21.4	17.97	8.83	23.98	X	6,543				From stimulation rpt: 4329 gal water, 2969 gal 70Q CO2 WF12, 46 lb J218. 25 lb/1000 gal polymer loading.	
	732.7	WR	11/18/2004	11.55	13.29	23.4	18.08	10.34	24.20	X	7,068				From stimulation rpt: 4596 gal water, 3027 gal 70Q CO2 WF12, 46 lb J218. 25 lb/1000 gal polymer loading.	
	768.4	WR	11/18/2004							X	7,031				"slickwater/CO2 assist"	
	830.6	WR	11/13/2004							X	8,092				"Frac: slickwater/CO2 assist-158 bbls"	
	1103	FU	11/13/2004	17.65				5.27		X	6,841				"Frac: slickwater/CO2 assit-162 bbls"	
	1163	FU	11/13/2004	14.75				5.27		X	9,274				"Frac: slickwater/CO2 assist-114 bbls"	
	1420	FU	11/13/2004	8.62				6.21		X	16,036				"Frac: slickwater/CO2 assit-210 bbls"	
	1505	FU	11/13/2004	8.76				9.48		X	10,866				"Frac: slickwater/CO2 assist-171 bbls"	
	1579	FU	11/13/2004	12.41				12.82		X	8				"Frac: slickwater/CO2 assist-169 bbls"	
	1598	FU	11/13/2004	11.38				11.03		X	16,919				"Frac: slickwater/CO2 assist-247 bbls"	
	1663	FU	11/13/2004	14.13				9.79		X	9,299				"Frac: slickwater/CO2 assist-263 bbls"	
24-11	447.8	WR	12/16/2005					8.09	28.28	X	7,131	2		1,476	"91 bbls linear gel"	No
	600.8	WR	12/16/2005					8.76	24.66	X	6,916				"102 bbls linear gel"	
	659.3	WR	12/16/2005					10.79	27.14	X	9,949				"122 bbls linear gel"	
	751.3	WR	12/16/2005					8.54	19.23	X	7,481				"111 bbls linear gel"	
	931.5	WR	12/16/2005					10.84	21.72	X	6,570				"114 bbls linear gel"	
	1033	FU	12/16/2005					10.79	20.58	X	10,177				"224 bbls linear gel"	
	1067	FU	12/16/2005							X	6,514				"135 bbls linear gel"	
	1094	FU	12/16/2005	14.48				3.03	12.89	X	14,887				"233 bbls linear gel"	
	1136	FU	12/16/2005							X	9,757				"137 bbls linear gel"	
31-10B	518.8	WR	12/30/2004	8.03	8.31	10.39		5.98		X	12,247	2,570		14,008	"Frac: slickwater...36.6 tons CO2, 125 bbls KCl (est)"	Yes
	783.6	WR	12/30/2004	13.73	10.78	17.42		6.84		X	9,525				"Frac: slickwater...28.5 tons CO2... 118 bbls KCl (est)"	
	873.6	WR	12/30/2004	16.90	11.56	18.49		8.89		X	6,804				"Frac: slickwater...20.4 tons CO2, 102 bbls KCl (est)"	
	1041	FU	12/30/2004	16.90	11.56	18.49		8.89		X	10,886				"Frac: slickwater…32.6 ton CO2, 143 bbls KCl (est)"	
	1396	FU	12/30/2004	10.09	9.45	14.78		9.45		X	13,608				"Frac: slickwater... 40.7 tons CO2, 185 bbls KCl (est)"	
	1486	FU	12/30/2004	9.48	13.82	21.55		9.85		X	13,608				"Frac: slickwater…40.7 tons CO2, 190 bbls KCl (est)"	
33-11B	602	WR	1/14/2005	8.52		19.55			24.20	X	8,238	0		185	"91 bbls slickwater"	No
	695.2	WR	1/14/2005	6.27		22.44			20.13	X	8,119				"94 bbls slickwater"	
	798	WR	1/14/2005	7.17		22.50		7.24	18.78	X	8,112				"148 bbls slickwater"	
	847	WR	1/13/2005	2.55		14.62		6.96	18.10	X	6,804				"377 bbls slickwater"	
	1044	FU	1/13/2005	14.75		18.65		9.24	18.55	X	9,525				"124 bbls slickwater"	
	1076	FU	1/13/2005	10.27	15.24	19.44		6.07	15.38	X	10,886				"155 bbls slickwater"	
44-11B	465.1	WR	1/11/2005							X	6,690	4		4,985	"182 bbls WF125/75Q CO2"	No
	483.1	WR	1/11/2005							X	7,199				"185.6 bbls WF125 75/65Q CO2"	
	540.1	WR	1/11/2005							X	7,430				"184 bbls WF125 75/65Q CO2"	
	879.3	WR	1/11/2005							X	7,212				"191 bbls WF125/75Q CO2"	

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	974.1	WR	1/11/2005							X 7,044					"288 bbls WF125/70Q CO2"	
	1041	FU	1/11/2005							X 11,412					"325 bbls WF125/70Q CO2"	
	1074	FU	1/11/2005							X 8,831					"298.5 bbls WF125/70Q CO2"	
21-14	619	WR	12/17/2004					8.61		X 6,532		3		1,886	"Sl ckwater, 92 bb 1…CO2 assist"	No
	684	WR	12/17/2004	16.82						X 7,121					"Slickwater, screen-out, 65 bbl…CO2 assist"	
	728.5	WR	12/17/2004	16.83				7.41		X 6,827					"Slickwater, 93 bbl…CO2 assist"	
	768.1	WR	12/17/2004	12.69				8.27		X 7,072					"Slickwater, 115 bbl…CO2 assist"	
	1077	FU	12/16/2004	12.13						X 6,808					"Slickwater, screen-out, 72 bbl…CO2 assist"	
	1401	FU	12/16/2004	10.68				4.85		X 10,845					"Slickwater, 161 bbl…CO2 assist"	
	1419	FU	12/16/2004	8.94				4.43		X 10,587					"Slickwater, 163 bbls...CO2 assist"	
	1447	FU	12/16/2004	11.00				7.63		X 8,246					"Slickwater, 144 bbl…CO2 assist"	
	1473	FU	12/16/2004	11.86				7.03		X 8,119					"Slickwater, 155 bbl…CO2 assist"	
	1558	FU	12/16/2004	11.17				7.33		X 10,791					"Slickwater, 175 bbl CO2 assist"	
	1643	FU	12/16/2004	9.51				8.62		X 11,939					"Slickwater, 190 bbl...CO2 assist"	
13-10	670	WR	12/7/2004	10.56				9.80		X 6,804		2		7,329	"Sl ckwater/CO2 assi st…20 tons CO2"	No
	761.1	WR	12/7/2004	12.05						X 6,804					"Slickwater/CO2 assist-95 bbls…20 otns CO2"	
	956.5	WR	12/7/2004	15.61						X 6,804					"Slickwater/CO2 assit-106 bbl…20 tons CO2"	
	982.1	WR	12/7/2004	11.05						X 6,804					"Slickwater/CO2 assist-108 bbls…20 tons CO2"	
	1003	WR	12/7/2004	7.33						X 8,165					"Slickwater/CO2 assist-120 bbls…243 tons CO2"	
	1100	FU	12/7/2004	9.83		28.0				X 6,804					"slickwater/CO2 assist-114 bbls…20 tons"	
	1184	FU	12/7/2004	7.71		29.0				X 6,804					"Slickwater/CO2 assist-119 bbls…20 tons"	
	1211	FU	12/7/2004	7.14		29.0				X 8,165					"Slickwater/CO2 assist-131 bbls…24 tons"	
	1377	FU	12/7/2004	10.56		31.0				X 10,886					"Slickwater/CO2 assist-164 bbls…20 tons"	
	1407	FU	12/7/2004	10.19		32.0				X 6,804					"Slickwater/CO2 assist-130 bbls…32 tons"	
	1475	FU	12/7/2004	11.03		30.0				X 10,886					"Slickwater/CO2 assist-168 bbls…32 tons"	
	1505	FU	12/7/2004	11.80		28.0				X 8,165					"Slickwater/CO2 assist-148 bbls…24 tons"	
	1571	FU	12/7/2004	10.97		29.0				X 8,165					"Slickwater/CO2 assist-151 bbls…24 tons"	
	1639	FU	12/7/2004	7.45		29.0		5.55		X 10,886					"Slickwater/CO2 assist-177 bbls…32.2 tons CO2"	
21-10B	1018	FU	1/24/2005	12.27				7.58		X 6,957		8		14,747	"100 bbls clean flu id"	No
	1079	FU	1/24/2005	13.97				8.62		X 9,458					"147 bbls clean fluid"	
	1292	FU	1/12/2005	14.48				8.96		X 9,056					"168 bbl clean fluid"	
43-11B	483.1	WR	1/27/2005							X 7,532		0		190	"199 bbls WF125 75Q CO2"	No
	498.7	WR	1/7/2005							X 6,923					"195.4 bbls WF125 75Q CO2"	
	517.2	WR	1/7/2005							X 5,418					"180 bbls WF125 75Q CO2"	
	563.6	WR	1/27/2005							X 6,319					"191 bbls WF125 75Q CO2"	
	862	WR	1/27/2005							X 7,702					"231 bbls WF125 75Q CO2"	
	933	WR	1/27/2005							X 8,581					"278 bbls WF125 75Q CO2"	
	961	WR	1/27/2005							X 8,383					"306 bbls WF125 75Q CO2"	
	1098	FU	1/27/2005							X 11,638					"338 bbls WF125 75Q CO2"	
42-10B	576.1	WR	2/3/2005							X 5,118		0		2,882	"175 bbls WF 125 75Q"	Yes
	660.2	WR	2/3/2005							X 6,998					"200 bbls WF 125 75Q"	
	752.2	WR	2/3/2005							X 9,656					"262 bbls WF 125 75Q"	

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	817.8	WR	2/3/2005							X	6,751				"206 bbls WF 125 75Q"	
	909.5	WR	2/3/2005							X	6,854				"208 bbls WF 125 75Q"	
	939.4	WR	2/3/2005							X	6,804				"WF 125 75Q"	
	1005	WR	2/2/2005							X	6,855				"240 bbls WF 125 75Q"	
	1062	FU	2/2/2005							X	8,165				"WF 125 70Q"	
	1081	FU	2/2/2005							X	9,329				"329 bbls WF 125 70Q"	
	1377	FU	2/2/2005							X	9,935				"339 bbls WF 125 70Q"	
	1467	FU	2/2/2005							X	14,077				"422 bbls WF 125 70Q"	
22-11B	680.9	WR	2/7/2005							X	6,804	0		817	"WF 125 70Q CO2"	No
	730.3	WR	2/7/2005							X	8,165				"WF 125 70Q CO2"	
	1050	FU	2/7/2005							X	8,165				"WF 125 70Q CO2"	
	1099	FU	2/7/2005							X	7,813				"272 bbls WF 125 70Q CO2"	
	1127	FU	2/7/2005							X	6,595				"285 bbls WF 125 70Q CO2"	
	1162	FU	2/4/2005							X	11,393				"340 bbls WF 125 70Q"	
32-10C	585.2	WR	2/10/2005							X	13,944	8		7,099	"347 bbls WF 125 75Q"	Yes
	649.2	WR	2/9/2005							X	6,459				"190.5 bbls WF 125 75Q CO2"	
	756.5	WR	2/9/2005							X	3,239				"163 bbls WF 125 75Q"	
	790	WR	2/9/2005							X	8,190				"237 bbls WF 125 75Q CO2"	
	867.5	WR	2/9/2005							X	6,329				"204.5 bbls WF 125 75Q CO2"	
	1031	WR	2/9/2005							X	9,371				"342 bbls WF 125 70Q CO2"	
	1059	WR	2/9/2005							X	6,768				"270.5 bbls WF 125 70Q CO2"	
22-11C	449.3	WR	2/16/2005							X	5,979	6		8,725	"179 bbls WF 125, 75Q CO2"	No
	620	WR	2/16/2005							X	6,566				"194 bbls WF 125, 75Q CO2"	
	759.6	WR	2/16/2005							X	8,375				"229 bbls WF 125, 75Q CO2"	
	857.7	WR	2/16/2005							X	6,838				"204 bbls WF 125, 75Q CO2"	
	880	WR	2/16/2005							X	6,878				"207.5 bbls WF 125, 75Q CO2"	
	926.3	WR	2/16/2005							X	6,688				"202.5 bbls WF 125, 75Q CO2"	
	1074	FU	2/16/2005							X	6,709				"230 bbls WF 125, 70Q CO2"	
44-4	1153	FU	3/8/2005					6.09	15.38	X	16,451	1,265		26,707	"160 bbls slickwater"	Yes
	1369	FU	3/8/2005					6.69	14.93	X	20,428				"178 bbls slickwater"	
	1411	FU	3/8/2005					8.80	16.29	X	15,947				"175 bbls slickwater"	
	1665	FU	3/8/2005					10.90	16.74	X	10,324				"107 bbls slickwater"	
12-12	598.6	WR	3/3/2005	10.73				7.55	22.62	X	13,900	0		187	"96 bbls slickwater"	No
	1111	FU	3/3/2005	7.26				6.12	15.61	X	11,423				"109 bbls slickwater"	
	1151	FU	3/3/2005	11.42				6.23	15.38	X	20,732				"183 bbls slickwater"	
33-2C	568.5	WR	2/24/2005	15.76				9.17		X	6,844	0		0	"2912 bbls 75Q slickwater"	No
	695.9	WR	2/24/2005	15.44				8.98		X	6,133				"4790 bbls 75Q slickwater"	
	759	WR	2/24/2005	12.51						X	7,304				"2111 bls 75Q slickwater"	
	789.1	WR	2/24/2005	13.11				8.69		X	6,542				"3846 bbls 75Q slickwater"	
	812	WR	2/24/2005	14.62				7.72		X	10,825				"5054 bbls 75Q slickwater"	
	835.2	WR	2/24/2005	17.07				7.58		X	6,758				"4002 bbls 75Q slickwater"	

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	1102	FU	2/24/2005	14.75				7.93		X	12,390				"7158 bbls 75Q slickwater"	
13-2B	429.5	WR	3/19/2005					6.00	23.98	X	6,720	0		3,944	"59 bbls slickwater"	No
	480.4	WR	3/19/2005					6.55	23.75	X	9,807				"70 bbls slickwater"	
	536.8	WR	3/19/2005					7.07	23.30	X	6,720				"67 bbls slickwater"	
	586.4	WR	3/19/2005					7.89	23.53	X	9,730				"67 bbls slickwater"	
	670	WR	3/19/2005					5.58	18.55	X	9,625				"70 bbls slickwater"	
	800.1	WR	3/19/2005					8.27	20.36	X	13,706				"128 bbls slickwater"	
	1063	FU	3/18/2005					9.10	18.78	X	7,253				"68 bbls slickwater"	
	1107	FU	3/18/2005							X	6,536				"66 bbls slickwater"	
	1128	FU	3/18/2005					7.17	16.51	X	6,720				"92 bbls slickwater"	
43-4	524.3	WR	3/16/2005	8.55				7.83	10.18	X	10,300	44	19,681		"3573 bbls 70Q x-linked gel…reservoir pressure 963 psi"	Yes
	645.3	WR	3/16/2005	14.60				7.21	10.18	X	7,165				"2555 bbls 70Q x-linked gel…reservoir pressure 1167 psi"	
	808.3	WR	3/16/2005	12.78				5.99	10.18	X	9,306				"2858 bbls 70Q x-linked gel…reservoir pressure 1466 psi"	
	954.3	WR	3/16/2005	10.00				10.39	10.18	X	9,525				"3074 bbls 70Q x-linked gel…reservoir pressure 1736 psi"	
	1053	FU	3/16/2005	16.64					10.18	X	7,719				"3424 bbls 70Q x-linked gel…reservoir pressure 1904 psi"	
	1156	FU	3/16/2005	15.49				5.56	10.18	X	20,518				"8293 bbls 70Q x-linked gel…reservoir pressure 2107"	
	1402	FU	3/16/2005	13.70					10.18	X	6,823				"3077 bbls 70Q x-linked gel…reservoir pressure 2531 psi"	
33-2B	430.4	WR	3/23/2005							X	7,121	31 5		,617	"56 bbls slickwater"	No
	549.2	WR	3/23/2005	10.65				5.80	20.58	X	8,258				"62 bbls slickwater"	
	565.7	WR	3/23/2005	12.45				7.34	23.07	X	20,318				"144 bbl slickwater"	
	676.7	WR	3/23/2005	13.80				6.30	19.45	X	6,985				"60 bbls slickwater"	
	824.2	WR	3/23/2005	14.13					20.13	X	13,574				"162 bbls slickwater"	
	863.5	WR	3/12/2005	10.97				9.80	21.49	X	6,439				"1442 bbls slickwater"	
14-3B	887.3	WR	4/2/2005	20.64				8.97	10.18	X	6,748	5		1,901	"54 bbls slickwater"	Yes
	941.8	WR	4/2/2005	14.94				10.25	21.04	X	11,520				"111 bbls slickwater"	
	1146	FU	4/2/2005							X	10,810				"1215 bbls slickwater"	
41-11B	498.3	WR	4/6/2005	3.00				4.54	19.45	X	3,835	12 640			"53 bbls slickwater…Flush with 23 bbl 6% KCL w/50% CO2""	No
	679.7	WR	4/8/2005	4.37				6.10	19.23	X	7,380				"60 bbls slickwater…Flush with 33.5 bbl 6% KCl"	
	713.5	WR	4/5/2005	0.00						X	7,213				"55 bbls slickwater…Flush with 34 bbl 6% KCL and 60% CO2"	
	840	WR	4/5/2005	12.47				7.02	18.55	X	10,851				"80 bbls slickwater…Flush with 40 bbls 6% KCL"	
	886.1	WR	4/5/2005	11.09				9.22	20.58	X	7,536				"61 bbls slickwater…Flush with 45 bbl 6% KCL"	
	1077	FU	4/5/2005	15.36				7.35	17.19	X	8,275				"105 bbls slickwater...Flush with 54 bbl 6% KCl"	
	1158	FU	4/5/2005					4.01	13.80	X	12,432				"170 bbls slickwater...Flush with 58 bbls 6% KCl"	
42-4B	526.4	WR	3/29/2005	9.63				8.16	26.01	X	13,608	0		8,857	"Flush with 17 bbl 6% KCL and 7 bbl CO2"	No
	730	WR	3/29/2005	16.11				9.64	23.53	X	6,804				"Flush with 36 bbl 6% KCL"	
	802.5	WR	3/29/2005	9.14				10.18	22.85	X	9,525				"Flushed with 40 bbl 6% KCL"	
	842.2	WR	3/29/2005	10.07						X	4,667				"Screen out 22.4 bbl into flush, 19.9 bbl shy of full flush…Pumped 81 bbl of clean fluid and 16 tons of CO2 + sand"	
	864.7	WR	3/29/2005	15.48		19.84		9.96	21.72	X	11,366				"126 bbl clean fluid and 27 ton CO2"	
	1136	FU	3/29/2005	12.15				10.46	19.45	X	14,063				"180 bbl clean fluid and 39 ton CO2"	
	1169	FU	3/29/2005	16.33		22.39		10.68	19.45	X	10,978				"165 bbl clean fluid and 30 ton CO2"	
21-11B	440.1	WR	4/12/2005	7.18				5.16	10.18	X	6,811	18	1,560		"54 bbls slickwater"	Yes

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	626.4	WR	4/12/2005 7.17					6.49	10.18	X		10,906			"77 bbls slickwater"	
	695.2	WR	4/12/2005 7.57					6.83	10.18	X		6,803			"55 bbls slickwater"	
	741.6	WR	4/12/2005 10.27					7.27	10.18	X		7,511			"58 bbls slickwater"	
	919.6	WR	4/12/2005 17.58					8.43	10.18	X		6,826			"63 bbls slickwater"	
	1027	FU	4/12/2005 9.19					6.32	10.18	X		9,740			"89 bbls slickwater"	
	1066	FU	4/12/2005 14.16					6.59	10.18	X		6,891			"74 bbls slickwater"	
	1102	FU	4/12/2005 11.09					6.14	13.80	X		7,018			"87 bbls slickwater"	
13-3W	456	WR	4/16/2005 17.07					7.58	26.69	X		6,483	3	1,340	"60 bbls slickwater"	Yes
	708.4	WR	4/16/2005 17.07					7.58	20.81	X		6,582			"74 bbls slickwater"	
	739.4	WR	4/16/2005 17.07					7.58	20.36	X		6,104			"66 bbls slickwater"	
	820.2	WR	4/16/2005 17.07					7.58	19.23	X		11,132			"93 bbls slickwater"	
	860.1	WR	4/16/2005 17.07					7.58	19.00	X		2,417			"68 bbls slickwater"	
	963.5	WR	4/16/2005 17.07					7.58	17.87	X		7,071			"100 bbls slickwater"	
	1363	FU	4/16/2005 17.07					7.58	13.35	X		6,720			"134 bbls slickwater"	
41-10B	546.2	WR	4/30/2005 11.58					7.14	23.30	X		5,285	0	293	"48 bbls slickwater"	Yes
	679.1	WR	4/30/2005 12.01					8.09	21.94	X		11,864			"82 bbls slickwater"	
	919.3	WR	4/30/2005 23.32					9.34	20.36	X		6,393			"53 bbls slickwater"	
	1081	FU	4/30/2005					0.00	17.64	X		13,494			Information on stimulation missing from completion report. From WOGCC (2014) "CO2 assist"	
34-28	605	WR	5/20/2005 13.61		13.56	18.61		8.62		X		8,165	0	0	"97 bbls 6% kcl 24.4 tons co2"	No
	816.3	WR	5/20/2005 7.89	14.08		22.83		8.09		X		8,165			"109-bbls 6% kcl 24.4 tons co2"	
	927.2	WR	5/16/2005 15.58		19.78	17.9	32.96	13.93		X		8,165			"115 bbls 6% kcl 24.4 tons co2"	
	951.6	WR	5/10/2005 19.43		13.21	21.1	24.11	11.76		X		8,811			"172.2 bbls total co2-27 tons"	
	1285	FU	4/29/2005 19.03		19.03	23.17		5.85		X		0			"Acidize w/750 gal KCl, 7.5% acid"	
	1367	FU	4/14/2005 14.26					7.89	15.83	X		11,197			"Total fluid pumped was 145.6 bbl, total slurry was 172 bbl, total CO2 was 33 tons…Left +/-10,000 pounds lbs sand in casing"	
	1392	FU	4/8/2005 15.17					4.14		X		0			"Acidize w/23 bbls kcl, 7.5% acid…Flush w/18 bbls kcl"	
	1562	FU	3/26/2005 17.93					10.03	16.51	X		10,886			"WF 125 Slickwater…Flush with 78 bbl 6% KCL and 50% CO2"	
32-3	575.2	WR	5/25/2005 17.06		18.62	20.68		8.40		X		6,133	91	50,290	"85-bbld 6% kcl 20.4 ton s co2"	No
	705.3	WR	5/25/2005 17.31		20.68	22.06		8.74		X		11,037			"125-bbls 6% kcl 32.6 tons co2"	
	910.7	WR	5/25/2005 12.25		20.68	23.44		9.47		X		7,021			"104-bbls 6% kcl 20.4 tons co2"	
	933.9	WR	5/25/2005 16.51		22.75	26.54		8.48		X		9,370			"127-bbls 6% kcl 28.5 tons co2"	
	1427	FU	5/25/2005 20.04		20.68	27.58		7.07		X		6,931			"133-bbls 6% kcl 20.4 tons co2"	
	1492	FU	5/25/2005 22.51		22.75	25.51		6.62		X		20,412			"245 bbls 6% kcl 61.1 tons co2"	
43-9	1546	FU	5/27/2005 9.63 24.13					5.41		X		8,066	2	20,928	"161-bbls 6% kcl 28.5 tons co2"	No
	1618	FU	5/27/2005 14.80		26.20					X		7,157			"143 bbls 6% kcl 20.4 tons co2"	
	1649	FU	5/27/2005 14.39		24.13	27.72		6.32		X		13,641			"200-bls 6% kcl 40.7 tns co2"	
	1697	FU	5/27/2005 20.26		24.13	29.99		8.55		X		17,557			"180-bbls 6% kcl 32.6 tons co2"	
22-3	775.4	WR	7/9/2005 16.20					7.65		X		10,210	0 0	19,153	"100 bbls fluid"	No
	842.5	WR	7/9/2005 13.54					9.48		X		7,354			"108 bbls fluid"	
	912	WR	7/9/2005 13.38					8.93		X		7,208			"185 bbls fluid"	
	970.8	WR	7/9/2005 15.69					10.34		X		11,387			"132 bbls fluid"	
	1166	FU	7/9/2005 27.03					6.41		X		13,950			"206 bbls fluid"	

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	1402	FU	6/17/2005	20.97				8.89		X		16,595			"183 bbls 70Q x-linked fluid"	
	1490	FU	6/17/2005	27.72				8.17		X		16,551			"225 bbls of 70Q x-linked fluid"	
	1550	FU	6/17/2005	21.34				9.93		X		16,664			"226 bbls of 70Q x-linked fluid"	
	1631	FU	6/17/2005	22.05		28.48		15.72	16.51	X		7,378			"193 bbls of 70Q x-linked fluid"	
44-3C	569.1	WR	6/3/2005	12.62				7.77		X		8,508	545	21,787	"88 bbls fluid" Cement squeeze on 7/7/2005 apparently due to well making water.	No
	662.3	WR	6/3/2005	12.50				7.47		X		10,678			"116 bbls fluid"	
	706.2	WR	6/3/2005	16.97				8.16	21.49	X		8,864			"101 bbls fluid"	
	819.9	WR	6/3/2005	17.23				9.19	21.26	X		7,072			"95 bbls fluid"	
	884.2	WR	6/3/2005	8.81				9.15	20.58	X		10,738			"121 bbls fluid"	
	1087	FU	6/3/2005	16.55				7.52	16.97	X		16,019			"213 bbls fluid"	
32-2	794.3	WR	3/28/2006	11.02		40.57		7.01	19.00	X		13,830	2	4,450	"181 bbls 6% KCl, 65Q CO2"	No
	919.6	WR	3/28/2006	11.81		18.12		9.43	20.36	X		12,448			"204 bbls 6% KCl, 65Q CO2"	
	1088	FU	3/24/2006	13.87		20.17		12.19	21.26	X		13,100			"Breakdown with 71 bbls 6% KCl...Frac w/226 bbls 6% KCl, 65Q CO2"	
	1498	FU	3/22/2006	10.54		19.59		10.03	16.74	X		12,938			"Breakdown w/90 bbls 6% KCL, 2 gal/1000 surfactant…Frac w/221 bbls 6% KCl, 65Q"	
	1570	FU	3/15/2006	17.93				7.25	14.70	X					"Breakdown w/24 bbls 6% KCl"	
33-12	557.8	WR	3/29/2006	9.00		13.90		8.00	24.88	X		9,089	8	5,520	"163 bbl 6% KCL and 28 ton CO2"	
	897.9	WR	3/29/2006	10.12		17.71		8.04	19.23	X		12,982			"190 bbl 6# KCL and 29 ton CO2"	
	1106	FU	3/29/2006	8.67		16.88		7.64	16.97	X		14,514			"226 bbl 6% KCL, and 30 ton CO2"	
	1443	FU	3/2/2006	17.04				9.44	16.74	X		15,743			"Total clean fluid 189 bbl, total slurry 227 bbl, total CO2 42 ton"	
	1543	FU	3/2/2006	17.46				9.95	16.74	X		10,982			"Total clean fluid 186 bbl, total slurry 212 bbl, total CO2 27 ton"	
	1576	FU	3/2/2006	15.26				9.63	16.51	X		10,121			"Total clean fluid 176 bbl, total slurry 201 bbl, total CO2 24 ton"	
	1604	FU	3/2/2006	19.47				20.48	23.07	X		10,502			"Total clean fluid 188.7 bbl, total slurry 213.6 bbl, total CO2 28 ton"	
	1626	FU	3/2/2006	20.01				12.84	18.10	X		10,455			"Total clean fluid 189.6 bbl, total slurry 214 bbl, total CO2 27 ton. Total injected 352 bbl"	
14-21																No
22-4	610.2	WR	4/3/2007							X		2,349	2	4,390	"86 bbls WF 118…nitrogen assist"	No
	671.8	WR	4/3/2007							X		2,215			"85 bbls WF 118…nitrogen assist"	
	786.4	WR	4/3/2007							X		2,096			"101 bbls WF 118…nitrogen assist"	
	928.1	WR	4/3/2007							X		2,274			"122 bbls WF 118…nitrogen assist"	
	1014	WR	4/3/2007							X		2,235			"108 bbbls WF 118…nitrogen assist"	
	1130	FU	4/3/2007							X		2,505			"110 bbls WF 118…nitrogen assist"	
	1476	FU	1/5/2007	18.20				12.82	18.55	X		12,655			"492 bbls Delta 140 15# xlink gel"	
	1512	FU	1/4/2007	12.07	21.72	40.0	24.06	11.25	16.74	X		25,129			"643 bbls 15# Delta x-link gel…Flush w/76 bbl slcik wtr"	
	1632	FU	1/4/2007	16.82	19.31	30	19.99	14.84	18.78	X		14,107			"440 bbls Delta 140 15# x-link gel…Flush w/83 bbl slick wtr"	
42-15	666.6	WR	3/20/2007							X		2,421	2	6,668	"143 bbls WF118 70Q N2"	No
	702.9	WR	3/20/2007							X		2,183			"146 bbls WF118 70QN2"	
	755.9	WR	3/20/2007							X		2,298			"150 bbls WF118 70QN2"	
	861.7	WR	3/20/2007							X		2,291			"160 bbls WF118 70QN2	
	906.8	WR	3/20/2007							X		2,230			"206 bbls WF118 70QN2"	
	1007	WR	3/20/2007							X		2,359			"167 bbls WF118 70Q N2"	
	1059	FU	3/20/2007							X		2,327			"121 bbls WF118 70QN2"	
	1081	FU	3/20/2007							X		2,277			"128 bbls WF 118 70N2"	
	1195	FU	3/20/2007							X		2,267			"165 bbls WF118 70QN2"	

Well Abbreviation	Top of Stimulation Interval (m bgs)	Completion or Stimulated Formation	Stimulation Date	Break Down Pressure (MPa)	Average Pressure During Stimulation (MPa)	Average Flow during Stimulation (bpm)	Max Pressure During Stimulation (MPa)	Instantaneous Shut-In Pressure (Mpa)	Fracture Gradient (MPa/km)	Hydraulic Fracturing	Acid Stimulation	Proppant (kg or sxs sand)	Oil Production (bbls)	Produced Water (bbls)	Description of Stimulation from Well Completion Reports and Sundry Notices	WOGCC Well File Review[31]
	1489	FU	3/20/2007	30.34				10.16	16.74	X		10,434			"485 bbls YF 116ST"	
	1554	FU	3/20/2007	12.07				5.31	13.35	X		20,853			"563 bbls YF 116ST"	
	1608	FU	3/20/2007	17.79	11.03	30.0		5.97	13.57	X					"632 bbls YF 116ST"	
41-26 ---		--- ---		--- ---	-- --- -	- ---	-- --- -					--	--- ---		P&A after completion in 2007. No apparent production well casing. No stimulation or production.	---

BWR – Basal Wind River Formation
WR – Wind River Formation
FU – Fort Union Formation
L – Lance Formation
MT – Meeteetse Formation
F- Frontier Formation
C – Cody Formation
MV - Mesaverde Formation

bbm = barrels per minute
bbls - barrels
sxs = sacks

Table SI C3. Summary of compounds used for well stimulation. Information from Material Safety and Data Sheets provided to EPA from Encana[35]

Compound	Cas No.	Product	Manufacturer	Percent Composition	Specified Product Use
acetic acid	64-19-7	FE-1A Acidizing Composition	Halliburton	30-60	additive
"	"	BA-20 Buffering Agent	Halliburton	10-30	buffer
acetic anhydride	108-24-7	FE-1A Acidizing Composition	Halliburton	60-100%	additive
acetone	67-64-1	MC-B-8630	Multi-Chem Group	15-40	biocide
alcohol (proprietary)	not provided	WFT 9527	Weatherford	1-5	flow enhancer
alcohol (oxylated)	not provided	Musol A Solvent	Halliburton	10-30	solvent
alcohols, C6—10, ethoxylated, sulfate, ammonium salts	68037-05-8	MC FA-4013	Multi-Chem Group	<8	foaming agent/scale & corrosion inhibitor combination
alkylated quaternary chloride	not provided	Clayfix- II Material	Halliburton	not provided	clay stabilizer
alkylamine salts	not provided	EC6106A Biocide	Nalco/Exxon Energy Chemicals	40-70	biocide
alkyl hexanol	not provided	HYFLO IV	Halliburton	5-10	surfactant
ammonium acetate	631-61-8	BA-20 Buffering Agent	Halliburton	60-100	buffer
ammonium bisulfite	10192-30-0	EC1385A	Nalco/Exxon Energy Chemicals	10-30	corrosion inhibitor
ammonium chloride	12125-02-9	CL-12	Halliburton	1-27	crosslinker
anionic surfactants	not provided	MC FA-4013	Multi-Chem Group	<20	foaming agent/scale & corrosion inhibitor combination
aromatic solvent	64741-68-0	MC DF-7120	Multi-Chem Group	<75	defoamer/emulsion breaker
2-bromo-2-nitro-1,3-propanediol	52-51-7	BE-6 Microbiocide	Halliburton	60-100	biocide
2-butoxyethanol	111-76-2	F104	Schlumberger	10-30	foaming agent
"	"	AQF-2 Foaming Agent	Halliburton	10-30	foaming agent
"	"	MC FA-4500	Multi-Chem Group	1-10	foaming agent
"	"	MC FA-4295	Multi-Chem Group	<10	foaming agent
"	"	MC FA-4001	Multi-Chem Group	<11	foaming agent/scale & corrosion inhibitor combination
"	"	MC FA-4013	Multi-Chem Group	<12	foaming agent/scale & corrosion inhibitor combination
"	"	F103	Schlumberger	10-30	surfactant
"	"	Musol Solvent	Halliburton	60-100	solvent
"	"	Musol A Solvent	Halliburton	60-100	solvent
"	"	WSP 9999	Weatherford	not provided	solvent
"	"	WSP 92011	Weatherford	15-40	not provided
"	"	Transfoam C	Weatherford	5-10	drilling foam
cationic polymer	not provided	L55	Schlumberger	10-30	clay stabilizer
copper iodide	7681-65-4	HAI-85M Acid Inhibitor	Halliburton	1-5	corrosion inhibitor
diammonium peroxidisulphate	7727-54-0	J218	Schlumberger	60-100	breaker
2,2-dibromo-3-nitrilopropionamide	10222-01-2	BE-3S Bactericide	Halliburton	60-100	biocide
"	"	B069	Baker Hughes	60-100	biocide
diethylene glycol	111-46-6	AQF-2 Foaming Agent	Halliburton	2-10	foaming agent
"	"	Triethylene glycol	Shell Chemicals	0.01-5.0	not provided
diesel fuel #2	68476-34-6	LGC-VI	Halliburton	30-60	liquid gel concentrate
"	"	LGC-8	Halliburton	30-60	liquid gel concentrate
"	"	J877	Schlumberger	30-60	guar polymer slurry
dimethyl formamide	68-12-3	HAI-85M Acid Inhibitor	Halliburton	10-30	corrosion inhibitor
d-limonene	5989-27-5	WFT 9527	Weatherford	3-7	flow enhancer
EDTA/copper chelate	not provided	CAT-3 Activator	Halliburton	10-30	activator
ester salt	not provided	F104	Schlumberger	30-60	foaming agent
ethanol	64-17-5	LOSURF-300M	Halliburton	30-60	surfactant
"	"	F104	Schlumberger	10-30	foaming agent

Compound	Cas No.	Product	Manufacturer	Percent Composition	Specified Product Use
ethoxylated alcohol	9016-45-9	WFT 9785	Weatherford	1-3	foaming agent
ethoxylated alcohol linear (1)	not provided	F103	Schlumberger	5-10	surfactant
ethoxylated alcohol linear (2)	not provided	F103	Schlumberger	5-10	surfactant
ethoxylated alcohol linear (3)	not provided	F103	Schlumberger	5-10	surfactant
ethylene glycol	107-21-1	WSP 9030	Weatherford	40-70	hydrate inhibitor
"	"	MC FA-4001	Mult-Chem Group	54-58	foaming agent/scale & corrosion inhibitor combination
"	"	MC FA-4500	Mult-Chem Group	<33	foaming agent
"	"	MC FA-4295	Mult-Chem Group	1-5	foaming agent
"	"	MC WC-7549	Mult-Chem Group	<70	water clarifier
"	"	Artictherm E-50	Quadra	47-53	heat transfer fluid
2-ethyl hexanol	104-76-7	Klean-Break	Weatherford	10-30	not provided
ethyl octynol	5877-42--9	HAI-85M Acid Inhibitor	Halliburton	1-5	corrosion inhibitor
glutaraldehyde	111-30-8	MC B-8630	Multi-Chem Group	10-30	biocide
heavy aromatic petroleum naptha	64742-94-5	HYFLO IV	Halliburton	30-60	surfactant
"	"	Pad acid with aromatic naphtha	Halliburton	10-50	pad acid
"	"	LOSURF-300M	Halliburton	10-30	surfactant
"	"	LOSURF-259	Halliburton	5-10	surfactant
hydrochloric acid	7647-01-0	Pad acid with aromatic naphtha	Halliburton	10-30	pad acid
"	"	Hydrochloric acid	Halliburton	30-60	solvent
hydrotreated light petroleum distillates	64742-47-8	B221B	Schlumberger	40-60	polymer slurry
inner salt of alkyl amines		HC-2	Halliburton	10-30	additive
isooctanol	26952-21-6	HYFLO IV	Halliburton	5-10	surfactant
isopropanol	67-63-0	LOSURF-259	Halliburton	30-60	surfactant
"	"	F103	Schlumberger	10-30	surfactant
"	"	MC DF-7120	Multi-Chem Group	not provided	defoamer/emulsion breaker
"	"	MC FA-4295	Multi-Chem Group	1-5	foaming agent
"	"	MC FA-4001	Multi-Chem Group	<8	foaming agent/scale & corrosion inhibitor combination
"	"	MC FA-4013	Multi-Chem Group	<3	foaming agent/scale & corrosion inhibitor combination
"	"	MC EB-1790	Mult-Chem Group	<1	emulsion breaker
"	"	Klean-Break	Weatherford	10-30	not provided
"	"	HAI-85M Acid Inhibitor	Halliburton	10-30	corrosion inhibitor
"	"	EC1385A	Nalco/Exxon Energy Chemicals	10-30	corrosion inhibitor
"	"	Transfoam C	Weatherford	10-30	drilling foam
"	"	WFT 97112W	Weatherford	1-3	mixture
"	"	EC6106A Biocide	Nalco/Exxon Energy Chemicals	20-40	Biocide
methanol	67-56-1	Klean-Break	Weatherford	7-13%	not provided
"	"	L55	Schlumberger	not provided	clay stabilizer
"	"	WSP 9030	Weatherford	40-70	hydrate inhibitor
"	"	WSP 92011	Weatherford	15-40	not provided
"	"	WFT 97112W	Weatherford	15-40	mixture
"	'	WFT 9785	Weatherford	10-30	foaming agent
"	"	MC FA-4295	Multi-Chem Group	1-25	foaming agent
"	"	MC FA-2013	Multi-Chem Group	<25	foaming agent/scale & corrosion combination
"	"	EC9037a Surfactant	Nalco/Exxon Energy Chemicals	20-40	surfactant
"	"	Methanol	Murex N.A.	99.8	methanol

Compound	Cas No.	Product	Manufacturer	Percent Composition	Specified Product Use
methyl isobutyl ketone	108-10-1	WFT 9527	Weatherford	1-5	flow enhancer
2- monobromo-3-nitrilopropionamide	1113-55-9	BE-3S Bactericide	Halliburton	1-5	biocide
naphthalene	91-20-3	HYFLO IV	Halliburton	5-10	surfactant
“	“	LOSURF-300M	Halliburton	0-1	surfactant
2,2`,2`-nitrilotriethanol	102-71-6	J318	Schlumberger	60-100	breaker
organic salt	not provided	FE-3A	Halliburton	60-100%	iron control agent
petroleum raffinates	not provided	Klean-Break	Weatherford	30-60	not provided
polyepichlorohydrin, trimethylamine quaternized	51838-31-4	Cla-Sta XP Additive	Halliburton	30-60%	clay stabilizer
polyether	not provided	EC9037A	Nalco/Exxon Energy Chemicals	20-40	surfactant
potassium hydroxide	1310-58-3	CL-31	Halliburton	<5	crosslinker
potassium metaborate	13709-94-9	CL-31	Halliburton	30-60	crosslinker
“	“	CL-31/Water Blend	Halliburton	5-10	crosslinker
propargyl alcohol	107-19-7	HAI-85M Acid Inhibitor	Halliburton	5-10	corrosion inhibitor
proprietary blend	not provided	MC FA-4001	Multi-Chem Group	<8	foaming agent/scale & corrosion inhibitor combination
proprietary blend	not provided	MC FA-4013	Multi-Chem Group	<12	foaming agent/scale & corrosion inhibitor combination
quaternary ammonium salts	not provided	HAI-85M Acid Inhibitor	Halliburton	10-30	corrosion inhibitor
sodium chloride	7647-14-5	HC-2	Halliburton	5-10	additive
sodium persulfate	7775-27-1	SP Breaker	Halliburton	60-100	breaker
toluene	108-88-3	WFT 9527	Weatherford	3-7	flow enhancer
triethylamine hydrochloride	593-81-7	EC1385A	Nalco/Exxon Energy Chemicals	1-5	corrosion inhibitor
triethylene glycol	112-27-6	Triethylene glycol	Shell Chemicals	95.0-99.9	not provided
1,2,4-trimethylbenzene	95-63-6	LOSURF-300M	Halliburton	0-1	surfactant
xylene	1330-20-7	WFT 9527	Weatherford	40-70	flow enhancer
“	“	MC DF-7120	Multi-Chem Group	not provided	defoamer/emulsion breaker
zirconium complex	not provided	CL-12	Halliburton	30-60	crosslinker

Table SI C4. Specified volumes of "gel" used with CO_2 foam during hydraulic fracturing between 2001 and 2002 (1 barrel or bbl = 42 gallons or 159 L)

Year	Production Well	Volume
2001	Pavillion Fee 11-3	51 bbls
"	Pavillion Fee 43-11	157 bbls
2002	Pavillion Fee 41-10	96 bbls
"	Pavillion Fee 33-11	221 bbls
"	Tribal Pavillion 43-10	646 bbls
"	Pavillion Fee 24-3B	169 bbls
"	Pavillion Fee 11-11B	728 bbls
"	Pavillion Fee 31-11	528 bbls
"	Pavillion Fee 23-3	92 bbls
"	Pavillion Fee 23-3	584 bbls
"	Pavillion Fee 32-11	715 bbls
"	Pavillion Fee 44-11	491 bbls
"	Pavillion Fee 14-3W	206 bbls
"	Pavillion Fee 13-11B	363 bbls
"	Pavillion Fee 14-3W	357 bbls

Table SI C5. Specified volumes of "WF-125, WF-130, WF-135, and WF-12" polymer slurries with CO_2 and N_2 foam during hydraulic fracturing from 2001 to 2007 (1 barrel or bbl = 42 gallons or 159 L)

Year	Production Well	Polymer Slurry	Use of 6% KCl solution	Use of 10% Methanol Solution	Foam	Volume of Polymer Slurry (per well)
2001	Tribal Pavillion 43-1	*WF-125*	Yes	No	CO_2	658 bbls
"	Tribal Pavillion 43-1	*WF-125*	Yes	No	CO_2	658 bbls
"	Pavillion Fee 21-10W	*WF-125*	Yes	No	CO_2	1420 bbls
"	Tribal Pavillion 12-5	*WF-125*	Yes	Yes	CO_2	506 bbls
"	Pavillion Fee 11-11	*WF-125*	Yes	Yes	CO_2	1,471 bbls
"	Pavillion Fee 13-12	*WF-125*	Yes	Yes	CO_2	915 bbls
"	Pavillion Fee 13-15	*WF-125*	Yes	Yes	CO_2	805 bbls
"	Tribal Pavillion 34-2	*WF-130*	Yes	Yes	CO_2	1,652 bbls
"	Tribal Pavillion 32-1	*WF-130*	Yes	Yes	CO_2	912 bbs
"	Tribal Pavillion 14-10	*WF-130*	Yes	Yes	CO_2	673 bbls
"	Pavillion Fee 34-3R	*WF-130*	Yes	Yes	CO_2	718 bbls
"	Pavillion Fee 12-11W	*WF-125, WF-130*	Yes	Yes	CO_2	927 bbls
"	Pavillion Fee 21-13	*WF-135*	Yes	Yes	CO_2	549 bbls
"	Pavillion Fee 13-11	*WF-135*	Yes	Yes	CO_2	1,155 bbls
"	Tribal Pavillion 43-2	*WF-135*	Yes	Yes	CO_2	1,177 bbls
2004	Tribal Pavillion 43-10B	*WF-12*		No	CO_2	~286 bbls
2005	Pavillion Fee 43-11B	*WF-125*	?	No	CO_2	362 bbls
"	Pavillion Fee 44-11B	*WF-125*	?	No	CO_2	1,472 bbls
"	Pavillion Fee 43-11B	*WF-125*	?	No	CO_2	1,543 bbls
"	Tribal Pavillion 42-10B	*WF-125*	?	No	CO_2	2,141 bbls
"	Pavillion Fee 22-11B	*WF-125*	?	No	CO_2	897 bbls
"	Tribal Pavillion 32-10C	*WF-125*	?	No	CO_2	1,564 bbls
"	Pavillion Fee 22-11C	*WF-125*	?	No	CO_2	1,446 bbls
2007	Pavillion Fee 22-4	*WF-118*	?	No	N_2	612 bbls
"	Tribal Pavillion 42-15	*WF-118, YF116ST*	?	No	N_2	1,386 bbls of WF-118 and 1,680 bbls of YF116ST

Table SI C6. Volumes of slickwater used for hydraulic fracturing (1 barrel or bbl = 42 gallons or 159 L)

Year	Production Well	Foam	Volume (per well)
2004	Tribal Pavillion 43-10B	CO_2	1,494 bbls
	Tribal Pavillion 33-10B	CO_2	3,432 bbls
	Tribal Pavillion 42-10	CO_2	122 bbls
	Pavillion Fee 13-10	CO_2	1,731 bbls
	Tribal Pavillion 21-14	CO_2	1,353 bbls
	Pavillion Fee 31-10B	CO_2	863 bbls
2005	Pavillion Fee 33-11B	None	949 bbls
	Tribal Pavillion 41-3	None	524 bbls
	Tribal Pavillion 33-2C ?		29,873 bbls
	Tribal Pavillion 42-3	None	201 bbls
	Blankebship Fee 4-8	None	121 bbls
	Tribal Pavillion 12-12	None	388 bbls
	Pavillion Fee 44-4	None	620 bbls
	Tribal Pavillion 33-2B	None	1,442 bbls
	Tribal Pavillion 13-2B	None	1,249 bbls
	Pavillion Fee 14-3B	None	1,380 bbls
	Pavillion Fee 41-11B	None	584 bbls
	Tribal Pavillion 21-11B	None	557 bbls
	Pavillion Fee 13-3W	None	595 bbls
	Pavillion Fee 34-3B	None	139 bbls
	Pavillion Fee 41-10B	None	183 bbls

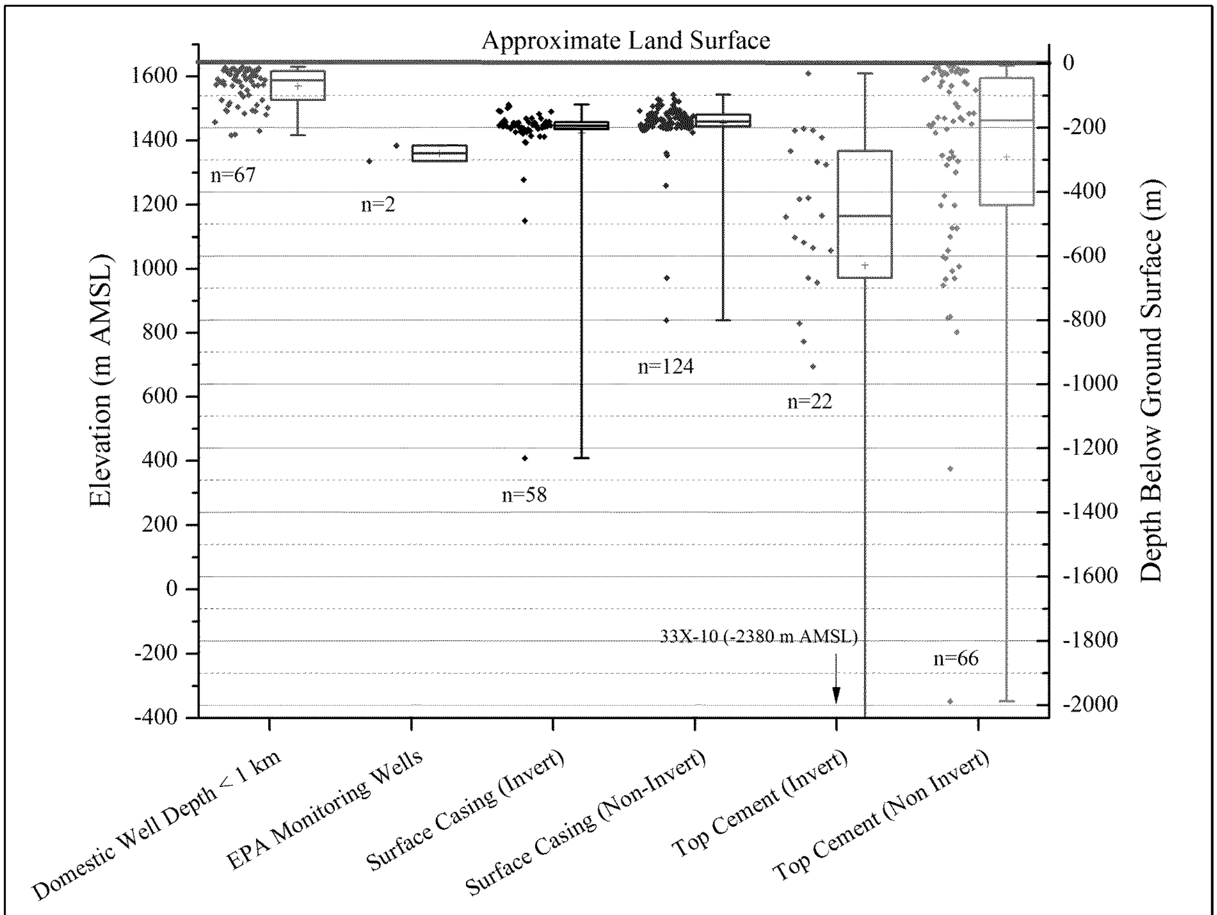

Figure SI C1. Elevation (m) Absolute Mean Sea Level (AMSL) of open intervals of domestic wells <1 km from production wells, EPA monitoring wells, surface casing with invert mud, surface casing without invert mud, top of primary cement with invert mud, and top of cement without invert mud. Median land surface elevation = 1636 m AMSL.

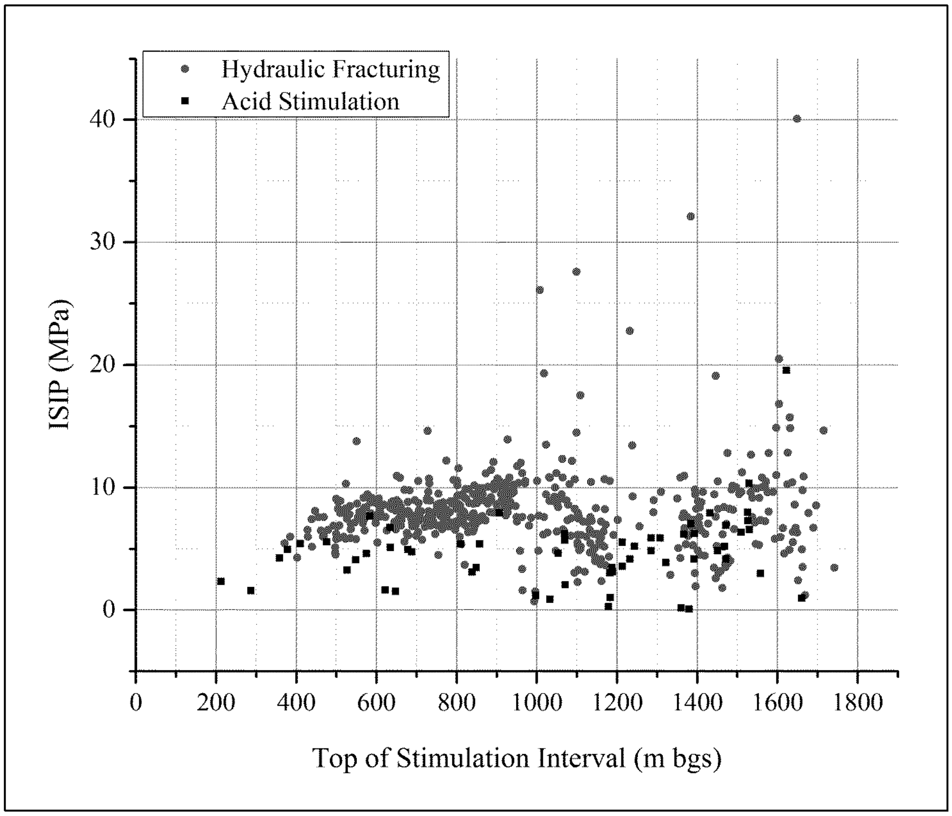

Figure SI C2. Instantaneous Shut-In Pressure (ISIP) values for well stimulation with depth

D – Extended Discussion on Impact to USDWs and Usable Water from Well Stimulation

D.1 Examples of Potential Loss of Zonal Isolation (Data Source: Well Completion Reports and Sundry Notices, Seach by API Number in Table SI C1)

Parted Casing and Cement Squeezes

Casing failure occurred at five production wells following well stimulation resulting in potential loss of zonal isolation.

Blankenship 4-8

Blankenship 4-8 was completed in March 1977. The base of surface casing is at 134.4 m bgs. On 3/26/1977, hydraulic fracturing was conducted at a depth of 1484 m bgs using *"500 gal 15% BDA frac w/102,000 gallons of gel water…300 scfpb nitrogen."* A cement bond log/variable density log (CBL/VDL) conducted at 2.76 MPa (400 psig) on 1/05/2005 indicated top of primary cement at 564 m bgs with high amplitude to 625 m bgs. During recompletion activities in January 2005, *"a hole"* in casing was noted between 312 to 322 m (1025 – 1062 ft) bgs. The time in which the hole in casing formed over a 28-year period between 1977 and 2005 is unknown. Since the base of surface casing is at 134.4 m bgs, there was 429 m of uncemented production casing below surface casing and no cement behind casing at depth of the hole. The potential for migration of stimulation fluid during hydraulic fracturing in 1977 was not assessed. The 1977 well completion report indicates tubing pressure at 4.41 MPa (640 psig) and casing pressure at 9.48 MPa (1375 psig) – well beyond hydrostatic pressure at 312 m bgs indicating likely gas migration at this depth and to presumably through the uncemented borehole to the depth of surface casing. Two cement squeezes were performed on 1/25/2005 and 1/27/2005 to remediate casing.

On 2/8/2005, 121 barrels of slickwater and CO_2 foam in a 6% KCl solution was used for hydraulic fracturing at 814 m bgs using, *"slickwater…121-bbls 6% KCl, 28.5 tons of CO2"* at a maximum stimulation pressure of 38.2 MPa (5546 psig). On 2/12/2005, hydraulic fracturing was conducted at a depth of 631 m bgs using *"Frac slickwater, 104 bbls."* at a maximum stimulation pressure of 39.4 MPa (5711 psig). In a well schematic dated 10/5/2011, *"parted casing"* was noted at 790.9 m (2595 ft) bgs with an assigned date of 12/21/2006. Parted casing, apparently induced during hydraulic fracturing, indicates loss of zonal isolation at 790.9 m bgs during hydraulic fracturing. There is no record of casing repair at this depth. In a sundry notice dated 11/7/2011, tubing, casing, and Bradenhead pressure were recorded as 0 psig. In a sundry notice dated 3/6/2012, a mechanical integrity test (MIT) conducted with a cast iron bridge plug (CIBP) at 616.9 m bgs (above parted casing) at 2.07 MPa (300 psig) indicated no bleed off.

USA Tribal 258 21-15 (Tribal 21-15)

USA Tribal 258 21-15 (Tribal 21-15) was completed in December 1979. The base of surface casing is at 188.7 m bgs. According to the well completion report, a CBL/VDL was conducted. However, the CBL/VDL is not in the well file. Hence, depth to primary cement and length of uncemented production casing below surface casing is unknown. In September 1982 during recompletion, a packer was set at 1004 m bgs and 1,000 gallons of a 15% HCl solution was used for acid stimulation at 799 m bgs. In October 1982, a cement squeeze was performed above the depth of acid stimulation at 472 m (1550 ft) bgs. The reason for a cement squeeze following stimulation was not provided.

On 3/7/2012, a sundry notice indicated that a MIT was conducted at Tribal 21-15 with *"failed casing...from 735? -1,105?"* [ft]. Failed casing was at a depth (224 m bgs) lacking primary cement. It is unclear when casing failed. On 8/14/2012, the WDEQ requested information from the Bureau of Land Management (BLM) on stimulation practices at Tribal 21-15 to evaluate the potential release of stimulation fluid at 224 m bgs (within depths of domestic ground water use). In a response dated 8/23/2012, BLM reiterated previously publicly available information on well completion at this production well thereby providing no additional insight on the potential for release of stimulation fluid through parted casing. The status of casing remediation at this production well is unknown. Bradenhead testing at this production well was either not conducted or documented.

Unit 41X-10

Unit 41X-10 was completed in January 1973. The base of surface casing is at 188.7 m bgs. A CBL/VDL conducted on 11/22/1972 indicated top of primary cement at approximately 427 m bgs. On 2/7/1973, hydraulic fracturing was conducted at a depth of 551.4 m bgs. From the well completion report, *"Frac treated...as follows...9# KCl wtr containing 5# J-133/1000 gal...2500 gal 15% HCl containing 5# J-133/1000 gal...9120 gal 9# KCl wtr containing 40# J-133, 20# J-110 and 1 gal F-63/1000 gal, 1# J-134 and 400 scf/bbl nitrogen...1460 gal 9# KCl wtr containing 560# J-133, 300# J-110, 15 gal F-63, 2 gal J-34 and 139,000 scf nitrogen...flushed w/9# KCl wtr containing 5# J-133/1000 gal...Well flowed back approx. 600 BLW since opened to pit...considerable amt of wtr."*

On 2/8/1979, hydraulic fracturing was conducted at a depth of 1232.6 m bgs. While perforating in the Fort Union Formation, *"Flowed well to pits continuously...Controlled well w/4% KCl wtr w/clay stabilizer & surfactant. Lost 80 bbls to form while doing so...acdz'd gross perf 4044-4450 w/4000 gals 15% HCl acid...Opened well to pit & cont'd to flw to pit overnight to cleanup." "Foam frac treated with 90,000 gals to qualify foam, 1,950,000 SCF nitrogen & 645 bbls gelled KCl wtr for sd carrying agent. Total load to rec 645 bls."*

In correspondence dated 5/27/1980, 41X-10 was recommended for plugging and abandonment (P&A) because of *"problems with water production and casing failure."* P&A occurred in 1981 with cement plugs. An updated well schematic for Unit 41X-10 appeared in the WOGCC Well Integrity Report[31]. This well schematic did not indicate casing failure. If well casing failure occurred during well stimulation above primary cement, release up through up the uncemented borehole could have occurred at or below the depth of surface casing.

Tribal Pavillion 42-10

Tribal Pavillion 42-10 was competed in June 1994 with acid stimulation at depths of 1448, 1620, 1643, and 1669 m bgs. Tribal Pavillion was recompleted in June 2001 with hydraulic fracturing in 7 stages between 1005 and 1380 m bgs. A CBL/VDL conducted on 12/15/2004 indicated top of primary cement at approximately 792 m bgs. The base of surface casing is at 190.8 m bgs. Hence, top of primary cement was 601 m below surface casing.

On 12/15/2004, hydraulic fracturing, (*"frac down casing"*) was conducted at a depth of 807.1 m - only 15 m below top of primary cement. The well completion report indicated use of *"122 bbls slickwater."* A stimulation report, one of only three for the entire field, posted on 8/9/2013, indicated use of *"4351 gal 70Q CO2 WF12"* consisting of *"4351 gal water and 34 lb J216."* A Material Safety Data Sheet for *"J216"* was not provided to EPA. Thus, the chemical composition of this product is unknown.

A cement squeeze was performed on 12/17/2004 (two days after hydraulic fracturing) for *"casing remediation"* at 774.2 m bgs (18 m above top of primary cement). If well casing integrity failure occurred during well stimulation, upward migration of stimulation fluid could have occurred above the top of primary cement to some undetermined depth below surface casing.

On 12/20/2004, another CBL/VDL was conducted at 3.45 MPa (500 psig). The CBL/VDL indicated high amplitude readings above 741 m bgs with chevrons (pipe connections) visible at 655 m bgs indicating poor casing to cement bonding. On 12/20/2004, 86 barrels of *"fluid"* was used for hydraulic fracturing at 763 m bgs (22 m below poor cement).

Tribal Pavillion 43-10B

Tribal Pavillion 43-10B was completed in January 2005. The base of surface casing is at 193.9 m bgs. A CBL/VDL conducted on 11/8/2004 indicated top of primary cement at 357 m bgs (163 m below surface casing). In November 2005, hydraulic fracturing was conducted over 13 intervals from 552 m to 1667 m bgs using ~80,000 gallons of slickwater with CO_2 assist and CO_2 foam using "*WF-12*" having a polymer loading of 25 lb/1000 gallons. A cement squeeze was performed subsequent to hydraulic fracturing on 1/14/2005 at 326.1 m bgs (31 m above the top of primary cement) to repair a *"casing leak."* If the "casing leak" occurred during well stimulation, upward migration of stimulation fluid could have occurred above the top of primary cement to some undetermined depth below surface casing. The last stimulation stage was on 11/11/2004. Hence, gas was free to migrate through casing to 357 m bgs prior to the cement squeeze more than two months later. Casing and tubing pressure are not provided at the time of well completion.

Cement Squeezes

Cement squeezes were performed above primary cement after, often days after, hydraulic fracturing without explanation at six production wells. In the absence of an explanation, potential migration of stimulation fluid above primary cement cannot be discounted.

Pavillion Fee 12-11B

Pavillion Fee 12-11B was completed in January 2005 with the base of surface casing at 167.9 m bgs. A CBL/VDL conducted on 12/29/2004, indicated top of primary cement at ~ 313 m bgs. On 12/29/2004, 110 barrels of *"CO_2 assisted gelled water"* was used for hydraulic fracturing at 429 m bgs. On 1/7/2005, a cement squeeze was performed above primary cement at 283 m bgs.

Pavillion Fee 21-10B

Pavillion Fee 21-10B was completed in February 2005 with the base of surface casing at 193.2 m bgs. On 1/6/2005 a CBL/VDL indicated top of primary cement at ~1265 m bgs (1072 m below surface casing). Good bonding *("GOBO")* was indicated starting at 1277 m bgs. On 1/12/2005, 168 barrels of *"clean fluid"* was used for hydraulic fracturing at 1292 m bgs – only 15 m below good bonding. On 1/17/2005 and 1/19/2005, days after hydraulic fracturing, cement squeezes were performed above top of primary cement at 1216 m and 1125 m bgs, respectively. On 1/24/2005, 247 barrels of *"clean fluid"* was used for hydraulic fracturing at 1049 m and 1079 m bgs. Again, days after hydraulic fracturing, cement squeezes were performed on 1/25/2005 and 1/27/2005 at 928 m and 244 m bgs, respectively.

Pavillon Fee 34-3B

Pavillion Fee 34-3B was completed in October 2004 with the base of surface casing at 196.6 m bgs. In October 2004, a CBL/VDL indicated top of primary cement at 838 m bgs (641 m below surface casing). In November 2004, *"clean fluid"* and CO_2 foam was used for hydraulic fracturing between 1039 m and 1637 m bgs. On 4/3/2005, a cement squeeze was performed at 823 m bgs. In this instance, a cement squeeze was apparently performed to enable hydraulic fracturing above primary cement. On

4/19/2005, 139 barrels of slickwater was used for hydraulic fracturing at 951 m bgs. On 4/21/2005, two days after hydraulic fracturing, another cement squeeze was performed at 256 m bgs.

Pavillion Fee 31-10B

Pavillion Fee 31-10B was completed in January 2005 with the base of surface casing at 192.0 m bgs. On 12/29/2004 a CBL/VDL indicated top of primary cement at 411 m bgs (219 m below surface casing) with high amplitude readings and a "railroad-like" pattern on the VDL extending to 488 m bgs. On 12/30/2004, ~ 36,000 gallons of slickwater with CO_2 assist was used for hydraulic fracturing between 519 m and 1508 m bgs. Shortly after hydraulic fracturing, cement squeezes were performed on 1/8/2005, 1/13/2005, and 1/18/2005 above primary cement at 381m, 305m, 213 m bgs, respectively.

Tribal Pavillion 12-12

Tribal Pavillion 12-12 was completed in March 2005 with the base of surface casing at 193.5 m bgs. A CBL/VDL conducted on 2/28/2005 indicated top of primary cement at 290 m bgs (97 m below surface casing). On 3/3/2005, 387 barrels of slickwater was used for hydraulic fracturing from 599 m to 1177 m bgs. On 3/9/2005, cement squeeze performed above primary cement at 259 m bgs.

Pavillion Fee 11-11B

Pavillion Fee 11-11B was completed in February 2002 with production casing cemented to the surface. However, a CBL/VDL conducted on 2/8/2002 indicated poor or spotty cement from 320 to 457 m bgs and production casing without cement between 777 m – 960 m bgs. This extensive interval uncemented production casing without cement was noted in the well completion report. On 2/18/2005, 232 barrels of *"clean fluid"* was used for hydraulic fracturing at 964 m bgs – only 4 m below this interval. A maximum stimulation pressure of only 1.3 MPa (190 psig) was noted indicating little resistance to flow and likely upward flow of stimulation fluid into the uncemented region.

D.2 Omissions to Bradenhead Testing

Bradenhead testing was not conducted at John K. Coolidge 1-4, Fike Tribal A-1, Tribal NP 31-11X, Tribal Pavillion 44-3, Tribal Pavillion 15-21X, and Tribal 21-14.

Pressure build-up following detection of brandenhead pressure was not measured at Ora Wells 14-12, Tribal Pavillion 24X-3, Tribal Pavillion 11-10, Tribal Pavillion 23-11, Pavillion Fee 42X-9, Tribal Pavillion 43-2, Pavillion Fee 34-11, Pavillion Fee 34-11, Pavillion Fee 21-10W, Pavillion Fee 11-3, Pavillion Fee 34-3B, and Tribal Pavillion 24-2.

Gas samples at well exhibing bradenhead pressure were not collected at Tribal Pavillion 31-15, IND 14-20-258-41X-2, Tribal Pavillion 33-2, Tribal Pavillion 44-1, Pavillion Fee 44-3C, Tribal Pavillion 32-10, Tribal Pavillion 44-1, and Pavillion Fee 21-10.

D.3 Summary of Bradenhead Testing with Water Flow

Water flow to the surface during Bradenhead testing occurred at 4 production wells. A summary of events, including information from well completion reports, cement bond/variable density logs (CBL/VDLs), and Sundry Notices is provided below.

Pavillion Fee 12-11W

Pavillion Fee 12-11W was completed in May 2001 with the base of surface casing at 131.1 m bgs. A CBL/VDL conducted on 4/21/2001 at Pavillion Fee 12-11W indicated top of primary cement at ~594 m bgs (463 m below surface casing). During Bradenhead testing in July 2012, 4,303 barrels (~180,700 gallons) of water flowed to the surface over a 15-day period at Pavillion 12-11W. Bradenhead pressures after 24-hour and 7-day shut-in periods were 85 and 979 kPa (142 psig), respectively. On 10/3/2012, a mechanical integrity test (MIT) was conducted above 764 m bgs (top perforation at 771 m bgs) at 3.4 MPa (500 psig) for 30 minutes – holding pressure without loss, verifying integrity of production well casing. Hence, the source of water was aqueous flow outside production casing at one or more depths. On 5/17/2013, cement squeezes were performed at 146 m and 442 m bgs.

Tribal Pavillion 13-2

Tribal Pavillion 13-2 was completed in March 2001 with the base of surface at 123.1 m bgs. A CBL/VDL conducted on 2/23/2001 at Tribal Pavillion 13-2, completed in March 2001, indicated top of primary cement at 198 m bgs (75 m below surface casing). During Bradenhead testing in January 2012, pressure after a 7-day shut-in period was 1.45 MPa (210 psig). During testing in July 2012, 3,785 barrels (~159,000 gallons) of water flowed to the surface over a 15-day period. Bradenhead pressures during a 7-day shut-in period was 0.965 MPa (140 psig).

Tribal Unit 44-10

Tribal Unit 44-10 was completed in December 1979 with the base of surface casing at 184.4 m bgs. A CBL/VDL conducted on 7/23/1979 at Tribal Unit 44-10, completed in December 1979, indicated top of primary cement at ~585 m bgs (401 m below surface casing). During Bradenhead testing in May 2012, 410 barrels (17,200 gallons) of water flowed to the surface during the first 8 hours of a 15-day test period. Bradenhead pressure during subsequent a subsequent 7-day shut-in period was 0.724 MPa (105 psig).

Tribal Pavillion 13-1

Tribal Pavillion 13-1 was completed in June 2001 with the base of surface casing at 163.1 m bgs. A CBL/VDL was not conducted. Thus of primary cement is unkown. During Bradenhead testing in July 2012, 6 barrels (~250 gallons) of water flowed to surface during the first hour of the 15-day testing period. Subsequent Bradenhead pressure after a 7-day shut-in period was 0.689 MPa (100 psig).

D.4 Summary of Major Ion Concentrations in Produced and Bradenhead Water

Table SI D1. Major Ions in Produced Water. Data obtained from sundry notices. NA for 33X-10 denotes not analyzed. Bradenhead samples denoted with **(B)** suffix

Well Abbrev	Stimulation Dates	Stimulation Fluids	Prod Water (bbls)	Sample Date	pH	SC (µS/cm)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	SO4 (mg/l)	Fe (mg/l)	CO3 (mg/l)	HCO3 (mg/l)	TDS (mg/l)
12-1	Nov 2001	KCl solution and CO2	653	8/8/2007	6.86	5,019	1323	270	71	30	1,753	34	48.45	0	903	4,260
14-1	Oct 1964, Apr 1993, Dec 1999	Undiluted diesel fuel, CO2 with methanol, 15% HCl solution	2,735	8/14/2007	7.15	3,996	785	160	205	29	956	49	190.60	0	902	3,325
22-1	Nov 2001	CO2 foam	892	8/8/2007	7.71	3,389	945	34	44	11	882	9	12.07	0	1,001	2,771
24-1	Mar 2001	No information on stimulation	817	8/8/2007	8.71	3,186	970	112	12	7	985	7	4.81	68	978	2,585
33-1	Sep 2001	No information on stimulation	3,176	8/8/2007	7.70	3,684	916	78	46	13	821	12	8.67	0	907	3,040
43-1	Aug 2001	WF125 in 6% KCl solution and CO2 foam	8,500	8/8/2007	7.73	2,322	667	21	15	4	503	5	1.97	10	919	1,796
44-1	Mar 2001	No information on stimulation	1375	8/8/2007	7.51	3,934	1051	94	39	13	1,263	8	13.87	0	737	3,269
24-2	Oct 2004	"clean fluid" and CO2	174	8/13/2007	8.28	4,940	1,479	202	29	14	1,774	7	0.25	7	1,235	4,188
32-2	Mar 2006	6% KCl solution, CO2, surfactant	4450	8/13/2007	6.01	3,823	768	268	67	14	817	11	57.90	0	807	3,167
33-2	Oct 1994, Oct 2000	15% HCl solution, "clean fluid", N2	1,263	8/13/2007	8.63	2,703	769	57	18	8	853	6	31.58	20	614	2,144
11-3	Dec 2001	6% KCl solution, CO2 foam, gel	1,895	8/13/2007	8.35	2,107	596	45	10	3	366	8	2.63	14	963	1,600
13-3W	Apr 2005	slickwater	1340	8/20/2007	6.61	5,702	1060	233	25	21	1,315	485	165.05	0	899	4,884
14-3W	Apr 2002	6% KCl solution, CO2, gel	5,695	8/14/2007	8.20	4,813	1538	88	7	7	1,089	8	4.11	12	2,243	4,072
24X-3	Nov 1965, Jun 1966	"P-12 solvent"	9653	8/14/2007	8.26	5,159	1572	47	2	3	1,094	17	5.95	11	1,094	4,388
31X-3	Aug 2001	unknown	1,215	8/13/2007	8.09	2,512	647	153	13	6	595	34	0.00	0	802	1,970
32-3	May 2005	6% KCl solution, CO2	50,290	8/13/2007	8.13	3,706	1264	17	13	3	1,194	4	4.82	35	1,072	3,060
33-3	May 1999	No information on stimulation	337	8/13/2007	8.99	3,270	1072	53	7	4	574	43	5.00	159	1,496	2,662
44-3	Apr 1999	15% HCl solution, 2% KCl solution	1,663	8/13/2007	8.34	2,364	697	20	19	4	387	5	4.48	11	1,113	1,834
1-4	May 1982	15% HCl soln, 3% HF soln, NH4Cl solution, foam. Possible recompletion in 2005	10,417	8/20/2007	8.10	2,438	608	81	22	6	585	135	2.00	0	788	1,902
42-4B	Apr 2005	6% KCl solution, CO2, "clean fluid"	8,857	8/20/2007	8.13	2,252	615	34	25	7	603	17	1.75	0	763	1,732
43-4	Mar 2005	70Q cross-linked gel	19,681	8/20/2007	8.30	3,343	1044	59	12	4	915	16	6.57	0	1,402	2,729
12-5	May 2001	WF125 in 6% KCl and 10% methanol solution, CO2 foam	3402	8/8/2007	8.88	2,874	903	87	3	3	797	2	1.17	100	1,067	2,300
12-7	Sep 2001	No information on stimulation	118	8/8/2007	5.93	10,022	2379	462	284	102	4,365	22	46.00	0	432	8,830
41-9	Aug 1979, Oct 2004	6% KCl solution, 70Q CO2 WF125, 7 1/2% HCl solutions	15,593	8/20/2007	8.29	2,342	654	30	18	5	693	6	3.94	17	615	1,814
42X-9	Feb 1999	No information on stimulation	10,083	8/20/2007	8.15	7,739	2247	106	9	7	793	13	13.72	0	4,301	6,745
12-10	Oct 2001	WF125, 6% KCl solution, CO2 foam	1,465	8/20/2007	8.08	2,876	827	90	10	6	808	9	7.52	29	1,012	2,302
14-10	Apr 2001	6% KCl and 10% methanol solution with additives and CO2	3,225	9/19/2007	6.30	6,661	1770	116	284	41	1,202	1,960	150.90	0	1,739	5,760
23-10W	Dec 2002	KCl solution, CO2	5,892	8/20/2007	8.00	3,742	1054	86	12	5	694	46	4.46	0	1,783	3,093
31-10	Jun 1994, Jan 2002	6% KCl solution, CO2 foam, 7 ½ HCl solution	15,504	8/20/2007	8.26	4,639	1497	25	13	6	1,044	6	14.39	12	2,025	3,913
32-10B	Mar 2002	6% KCl solution, CO2	4,727	8/14/2007	8.21	5,063	1593	17	10	6	1,022	4	3.36	10	2,152	4,300
32-10C	Feb 2005	WF125 with CO2	7,099	8/20/2007	8.05	1,779	421	15	15	3	131	175	1.82	0	630	1,300
33X-10	Feb 1965	"MCA", 15% HCl solution	?	3/29/1965	NA	NA	1298	NA	11	3	940	305	NA	72	1,342	3,971
33-10	Apr 1999	6% KCl solution, CO2, linear gel, 15% HCl solution	2,547	8/20/2007	7.62	4,409	1220	218	12	6	894	46	5.03	0	2,254	3,703
41-10	Jan 2002	6% KCl solution, CO2 foam	157	8/14/2007	5.90	21,177	2499	1,911	1,771	131	5,945	2,063	70.60	0	3,358	19,020
43-10	Sep 1994, Feb 2002	6% KCl solution, CO2 foam, gel	28,467	8/28/2007	6.96	5,064	1656	57	6	3	1,280	292	71.95	0	1,873	4,301
11-11	May 2001	WF125 in 6% KCl and 10% methanol with CO2 foam and additives	9,051	8/13/2007	7.08	2477	656	68	30	5	432	12	59.80	0	1,048	1,938
12-11	Oct 1993, Nov 2004	2% KCl solution, CO2 foam	8,451	8/14/2007	7.11	2,576	753	120	22	6	411	135	50.25	0	1,062	2,028
12-11B	Dec 2004	CO2 with gelled water	731	8/14/2007	8.45	2,941	816	194	11	9	633	7	5.66	31	1,296	2,362
21-11	Mar 1979	2, 3, and 7 ½% HCl solutions with additives, "YE4P5D fluid"	335	8/13/2007	7.61	3,304	938	123	40	11	1,079	9	27.45	0	762	2,693
44-11	Feb 2002	6% KCl solution with CO2 foam and gel	1,643	8/28/2007	5.59	2,140	510	29	39	3	363	255	109.20	0	647	1,630
33-12	Mar 2006	6% KCl solution, CO2, "clean fluid"	5520	8/14/2007	7.98	2,718	745	84	18	8	611	43	4.47	0	993	2,158
42X-12	Jan 1974	15% HCl solution, Possible recompletion in 2004	295	8/14/2007	7.20	1,619	303	144	23	3	545	14	13.30	0	90	1,154
21-14	Dec 2004	Slickwater with CO2	1,886	8/28/2007	7.53	5,242	1361	253	55	15	1,522	7	4.80	0	1,431	4,464
13-1 **(B)**				4/26/2012	10.86	33196	2700	6000	39	1.6	88	2100	1.67	17000	<2	30000
13-2 **(B)**				4/24/2012	9.57	1341	230	3.7	32	2.7	53	170	7.36	110	290	900
44-10 **(B)**				4/23/2012	8.64	903	280	9.6	15	2.3	7.1	16	6.45	40	240	500
12-11W **(B)**				4/24/2012	9.16	1056	180	3.1	7.4	2.5	67	130	4.88	37	210	640

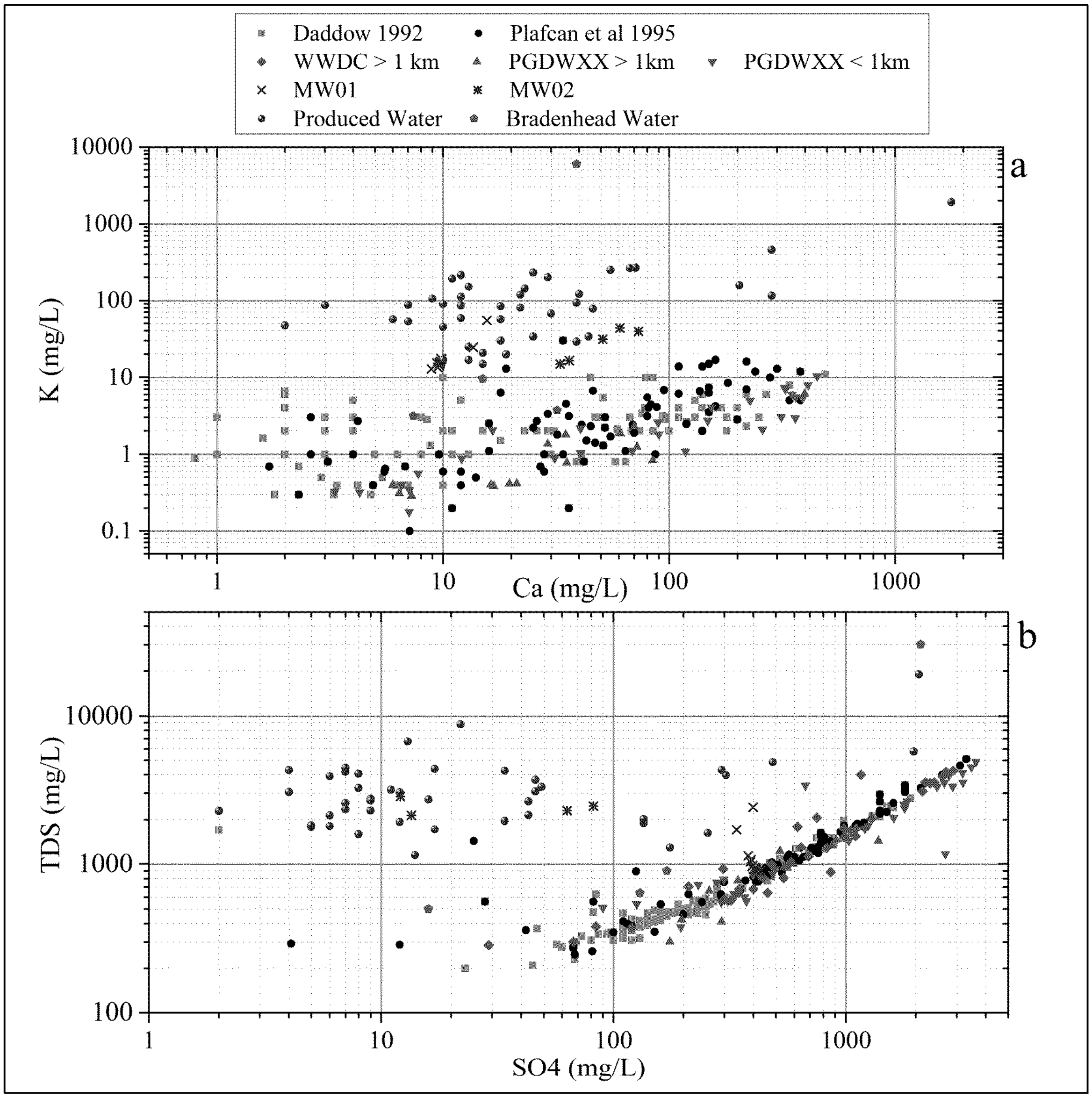

Figure SI D1. (a) Potassium concentration as a function of calcium concentration and (b) total dissolved solids (TDS) concentration as a function of sulfate concentration for the Wind River Indian Reservation (Daddow 1992)[5], Fremont County (Plafcan et al. 1995)[26], domestic wells sampled by the Wyoming Water Development Commission (WWDC) greater than 1 km from production wells, domestic wells (PGDWXX) less than and greater than 1 km from production wells, EPA monitoring wells MW01 and MW02, produced water samples, and bradenhead water samples. Mean values are represented for domestic well locations sampled more than once. Produced water and bradenhead locations were sampled once. Measurement at MW01 and MW02 represent samples collected during Phase III, IV, and V sample events to illustrate variability. TDS values for PGDWXX wells estimated from Daddow (1995) TDS (mg/L) = 0.785*specific conductance (µS/ cm)-130 (n=151, r^2=0.979)

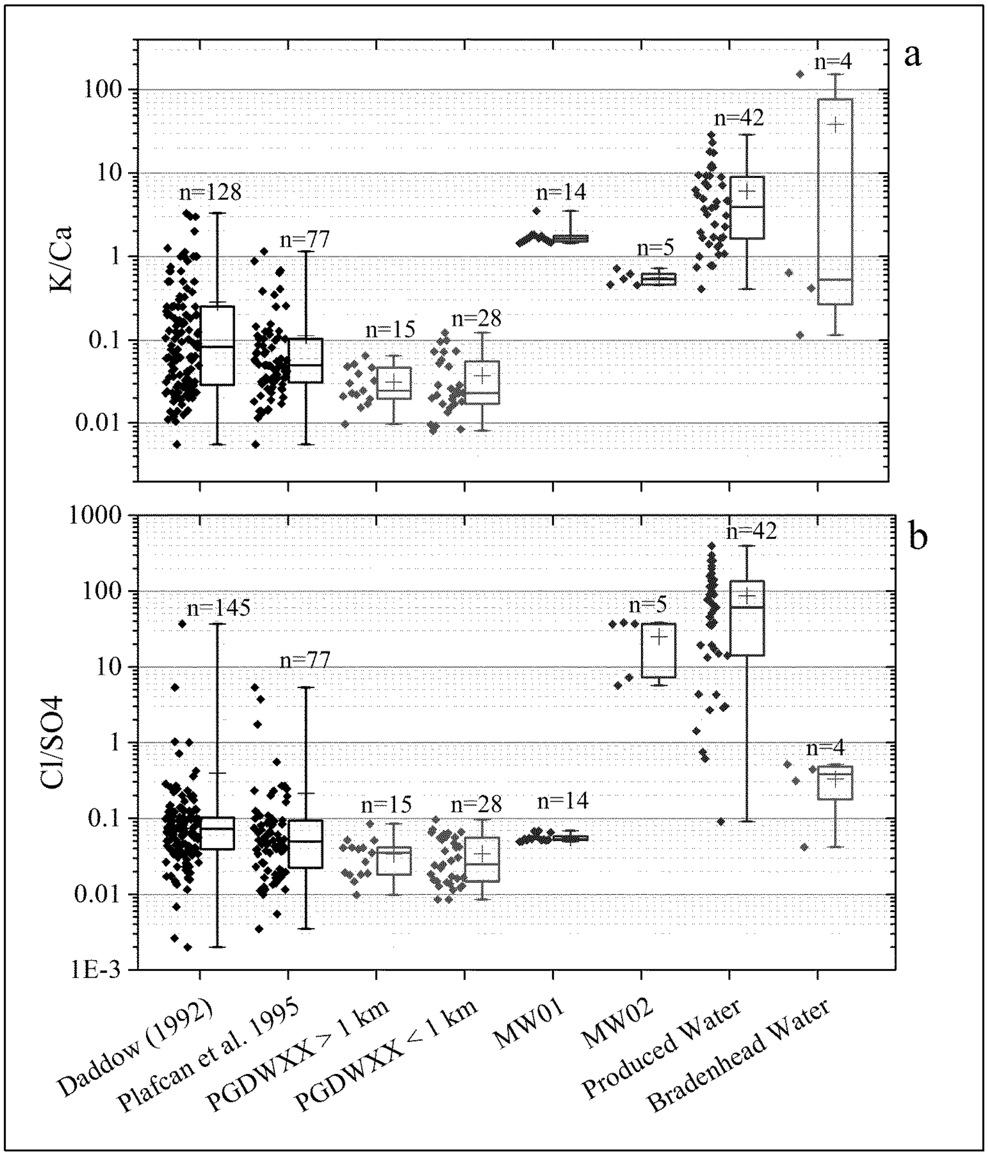

Figure SI D2. (a) Ratio of potassium to calcium and (b) chloride to sulfate concentrations for the Wind River Indian Reservation (Daddow 1992)[5], Fremont County (Plafcan et al. 1995)[26], domestic wells (PGDWXX) less than and greater than 1 km from production wells, EPA monitoring wells MW01 and MW02, produced water samples, and bradenhead water samples. Mean values are represented for domestic well locations sampled more than once. Produced water and bradenhead locations were sampled once. Measurement at MW01 and MW02 represent samples collected during Phase III, IV, and V sample events to illustrate variability.

D.5 Summary of Fixed Gases, Light Hydrocarbon, and BTEX Analyses in String and Bradenhead Gas

Table SI D2. String gas and bradenhead gas samples collected at production wells having sustained casing pressure. Concentrations in mole fractions x 100. Data obtained using API number in Table SI C1

Well	Sample Date	Gauge Pressure (MPa)	T (C)	Nitrogen	Carbon Dioxide	Methane	Ethane	Propane	iso-butane	Butane	iso-pentane	Pentane	Hexanes	Heptanes	Octanes	Nonanes	Decanes +	Benzene	Toluene	Ethylbenzene	xylenes	sum	C1/C1-C5)
String Gas Samples																							
13-1	6/11/2012	0.31	19	0.7266	0.0000	91.9740	4.7594	1.3181	0.4097	0.3223	0.1541	0.0885	0.0968	0.0780	0.0443	0.0030	0.0000	0.0116	0.0099	0.0004	0.0035	100.0002	0.934104
22-1	6/11/2012	2.69	19	0.8759	0.0709	92.8305	4.8352	0.0000	0.4877	0.4158	0.1787	0.1067	0.0997	0.0598	0.0259	0.0018	0.0000	0.0095	0.0003	0.0001	0.0014	99.9999	0.945434
13-2	3/5/2012	0.04	?	0.5499	0.0947	91.0554	4.3084	1.5168	0.5086	0.4560	0.3103	0.1995	0.3069	0.2921	0.2429	0.0188	0.0547	0.0331	0.0390	0.0006	0.0123	100.0000	0.933556
13-2B	6/21/2012	0.10	29	0.7071	0.0733	91.0681	4.8186	1.4356	0.4963	0.4280	0.2419	0.1538	0.1977	0.1692	0.1231	0.0141	0.0053	0.0267	0.0231	0.0013	0.0168	100.0000	0.930177
32-2	6/21/2012	0.26	27	0.6555	0.0052	92.4055	4.4755	1.1925	0.3879	0.3180	0.1612	0.0966	0.1117	0.0908	0.0596	0.0056	0.0017	0.0140	0.0115	0.0006	0.0068	100.0002	0.93824
33-2B	3/5/2012	0.00	21	0.6409	0.0940	92.1420	4.4226	1.3698	0.3864	0.3142	0.1595	0.0954	0.1176	0.1014	0.0925	0.0131	0.0123	0.0129	0.0138	0.0008	0.0108	100.0000	0.936936
13-3W	4/4/2012	0.26	15	0.3936	0.0502	91.7674	4.4037	1.5981	0.4771	0.4425	0.2330	0.1477	0.1640	0.1525	0.0942	0.0117	0.0045	0.0236	0.0215	0.0027	0.0122	100.0002	0.93298
22-3	6/11/2012	0.37	19	0.6833	0.0005	94.3455	3.3703	0.6320	0.2546	0.1749	0.1493	0.0771	0.1324	0.1120	0.0416	0.0047	0.0022	0.0149	0.0003	0.0014	0.0030	100.0000	0.956853
32-3	4/4/2012	0.27	13	0.3921	0.1865	94.5473	3.6026	0.8409	0.1526	0.1131	0.0410	0.0218	0.0259	0.0323	0.0220	0.0037	0.0018	0.0048	0.0060	0.0006	0.0049	99.9999	0.953812
44-3C	4/4/2012	1.79	21	0.4216	0.1036	94.4928	3.3318	0.8565	0.2389	0.1772	0.0932	0.0517	0.0695	0.0763	0.0559	0.0069	0.0000	0.0125	0.0072	0.0006	0.0040	100.0002	0.955341
43-4	4/4/2012	0.22	18	0.3756	0.0295	95.5235	3.1025	0.5134	0.1551	0.0871	0.0564	0.0247	0.0438	0.0485	0.0261	0.0037	0.0005	0.0060	0.0019	0.0002	0.0015	100.0000	0.962442
44-4	4/4/2012	0.26	18	0.3952	0.1602	93.4057	3.4166	1.2606	0.4024	0.2753	0.1580	0.0866	0.1206	0.1420	0.0984	0.0193	0.0096	0.0211	0.0127	0.0054	0.0102	99.9999	0.948813
12-5	6/11/2011	2.96	19	0.9390	0.0000	91.3650	4.9090	1.5679	0.4548	0.3678	0.1574	0.0912	0.0803	0.0419	0.0172	0.0013	0.0000	0.0060	0.0000	0.0002	0.0009	99.9999	0.929442
43-9	4/4/2012	0.32	19	0.5128	0.6048	93.4457	3.6813	0.9650	0.2221	0.1402	0.0846	0.0418	0.0775	0.0989	0.0663	0.0144	0.0032	0.0167	0.0119	0.0042	0.0086	100.0000	0.950869
13-10	12/23/2011	0.28	-12	0.4951	0.0592	93.8277	3.7263	0.9381	0.2886	0.2159	0.1154	0.0656	0.1011	0.1036	0.0596	0.0000	0.0000	0.0021	0.0020	0.0000	0.0000	100.0003	0.949927
31-10	5/14/2012	0.65	-11	0.3529	0.0006	93.9675	3.8277	0.9373	0.3053	0.2356	0.1307	0.0653	0.0851	0.0703	0.0190	0.0000	0.0000	0.0024	0.0003	0.0000	0.0000	100.0000	0.948847
32-10C	3/5/2012	?	?	0.4696	0.1336	94.0435	3.5933	0.8749	0.2624	0.1923	0.1063	0.0628	0.0875	0.0693	0.0518	0.0010	0.0330	0.0097	0.0087	0.0000	0.0002	99.9999	0.952177
41-10B	3/2/2012	0.22	21	0.5704	0.0467	92.6355	4.2192	1.0353	0.3903	0.3289	0.1784	0.1130	0.1568	0.1450	0.1242	0.0106	0.0039	0.0174	0.0194	0.0044	0.0007	100.0001	0.94207
42-10B	3/5/2012	?	?	0.4577	0.0592	93.3702	3.8301	1.1094	0.3318	0.2681	0.1430	0.0841	0.1161	0.1048	0.0851	0.0083	0.0044	0.0126	0.0116	0.0031	0.0004	100.0000	0.946365
44-10	4/23/2012	0.30	-11	0.3580	0.2090	95.0794	3.5282	0.4236	0.1392	0.0760	0.0502	0.0222	0.0462	0.0445	0.0208	0.0000	0.0000	0.0019	0.0008	0.0000	0.0000	100.0000	0.959144
12-11	6/25/2012	0.19	14	0.3545	0.3991	95.1965	3.0569	0.3532	0.1780	0.0498	0.0784	0.0258	0.0875	0.1036	0.0730	0.0160	0.0040	0.0192	0.0005	0.0006	0.0034	100.0000	0.964678
12-11W	6/11/2012	0.18	19	0.4691	0.0575	94.1256	3.3829	0.8745	0.2632	0.2075	0.1173	0.0695	0.1113	0.1372	0.1090	0.0133	0.0133	0.0194	0.0163	0.0009	0.0122	100.0000	0.95404
21-11	6/11/2012	0.17	19	0.4672	0.1165	94.1805	3.7227	0.0000	0.3247	0.2825	0.1680	0.1070	0.1679	0.1887	0.1626	0.0231	0.0081	0.0274	0.0280	0.0023	0.0229	100.0001	0.958164
32-11	10/6/2011	0.22	13	0.5223	0.0097	93.7030	3.8213	0.9190	0.3210	0.2361	0.1410	0.0732	0.0947	0.0793	0.0513	0.0029	0.0000	0.0139	0.0089	0.0025	0.0000	100.0001	0.948866
41-11B	3/2/2012	0.21	?	0.8591	0.1052	92.4548	3.9281	0.7011	0.4578	0.3977	0.2541	0.1654	0.2434	0.1975	0.1412	0.0085	0.0386	0.0230	0.0209	0.0026	0.0009	99.9999	0.946826
Bradenhead Gas Samples																							
13-1 BH	6/11/2012	0.33	19	2.8060	0.0000	92.2935	3.9441	0.0000	0.3635	0.2491	0.1345	0.0674	0.0757	0.0390	0.0173	0.0025	0.0000	0.0069	0.0001	0.0004	0.0000	100.0000	0.955873
22-1 BH	6/11/2012	0.15	19	3.0339	0.0000	91.4958	3.8633	0.9749	0.3655	0.0565	0.1382	0.0025	0.0328	0.0161	0.0179	0.0020	0.0001	0.0001	0.0000	0.0005	0.0000	100.0001	0.949195
13-2 BH	3/5/2012	?	?	3.4581	0.0000	90.7353	3.8201	1.0743	0.3865	0.2301	0.1178	0.0574	0.0641	0.0285	0.0188	0.0010	0.0020	0.0043	0.0013	0.0000	0.0005	100.0001	0.945975
13-2B BH	6/21/2012	1.17	31	0.7833	0.0000	92.4048	4.5145	1.2547	0.4110	0.3039	0.1383	0.0788	0.0668	0.0272	0.0093	0.0008	0.0000	0.0037	0.0014	0.0001	0.0014	100.0000	0.93758
32-2 BH	6/21/2012	0.72	26	0.6373	0.0000	92.4717	4.2972	1.1004	0.3680	0.2957	0.1703	0.1059	0.1694	0.1836	0.1302	0.0072	0.0002	0.0297	0.0253	0.0009	0.0070	100.0000	0.940988
33-2B BH	3/5/2012	0.00	21	0.7500	0.0000	91.9483	4.5196	1.4354	0.3864	0.3251	0.1814	0.1162	0.1582	0.1029	0.0503	0.0000	0.0056	0.0123	0.0080	0.0000	0.0002	99.9999	0.93496
13-3W BH	4/4/2012	0.19	18	0.5851	0.0000	92.4747	4.1781	1.6185	0.3771	0.3383	0.1425	0.0863	0.0788	0.0592	0.0371	0.0049	0.0007	0.0082	0.0064	0.0004	0.0037	100.0000	0.936966
22-3 BH	6/11/2012	0.07	19	0.7972	0.0000	92.2055	4.3671	1.4490	0.3797	0.3076	0.1496	0.0874	0.0941	0.0685	0.0377	0.0117	0.0125	0.0111	0.0078	0.0042	0.0093	100.0000	0.93689
32-3 BH	4/4/2012	1.51	12	0.6943	0.0000	93.1825	4.3036	1.1017	0.3078	0.2283	0.0891	0.0444	0.0274	0.0106	0.0062	0.0005	0.0005	0.0015	0.0011	0.0005	0.0001	100.0001	0.942566
44-3C BH	4/4/2012	1.24	13	0.7282	0.0000	92.5420	4.4161	1.3389	0.3818	0.3086	0.1263	0.0694	0.0529	0.0222	0.0081	0.0006	0.0001	0.0031	0.0010	0.0000	0.0004	99.9997	0.937846
43-4 BH	4/4/2012	0.81	18	1.0322	0.0000	92.4099	4.3012	1.4523	0.3484	0.2765	0.0858	0.0434	0.0251	0.0129	0.0072	0.0010	0.0002	0.0017	0.0011	0.0008	0.0002	99.9999	0.938331
44-4 BH	4/4/2012	0.48	18	0.7962	0.0000	91.2149	4.5748	1.8933	0.5013	0.4390	0.1898	0.1209	0.1229	0.0870	0.0418	0.0027	0.0003	0.0112	0.0036	0.0001	0.0000	99.9998	0.928463
12-5 BH	6/11/2011	0.00	19	99.4568	0.0503	0.1119	0.0111	0.3174	0.0074	0.0052	0.0081	0.0069	0.0132	0.0060	0.0043	0.0000	0.0002	0.0012	0.0000	0.0000	0.0000	100.0000	0.247293
43-9 BH	4/4/2012	0.17	17	1.5314	0.0002	90.4485	4.2953	2.0623	0.6302	0.4586	0.2044	0.1247	0.1145	0.0731	0.0352	0.0035	0.0005	0.0105	0.0041	0.0002	0.0028	100.0000	0.92873
13-10 BH	12/23/2011	0.16	-12	1.3915	0.0000	91.9284	3.9110	1.4602	0.4180	0.3632	0.1730	0.1094	0.1271	0.0540	0.0310	0.0000	0.0000	0.0328	0.0003	0.0000	0.0000	99.9999	0.94023
31-10 BH	5/14/2012	0.14	-12	0.8255	0.0005	92.0103	4.5227	1.5013	0.3920	0.3318	0.1379	0.0830	0.0826	0.0602	0.0370	0.0099	0.0000	0.0011	0.0020	0.0024	0.0000	100.0002	0.934598
32-10C BH	3/5/2012	0.07	21	1.4023	0.0000	92.2150	4.0826	1.3552	0.3486	0.2593	0.1280	0.0720	0.0711	0.0373	0.0153	0.0018	0.0041	0.0047	0.0018	0.0005	0.0003	99.9999	0.941122
41-10B BH	3/2/2012	1.17	21	0.7897	0.0000	93.3746	4.2654	0.9129	0.2833	0.2509	0.0666	0.0303	0.0150	0.0061	0.0000	0.0000	0.0006	0.0009	0.0034	0.0000	0.0003	100.0000	0.944761
42-10B BH	3/5/2012	0.07	?	1.1921	0.0000	92.0918	4.2286	1.3753	0.3731	0.3002	0.1512	0.0921	0.0950	0.0542	0.0336	0.0000	0.0036	0.0061	0.0029	0.0000	0.0002	100.0000	0.938869
44-10 BH	4/23/2012	0.14	-11	1.3997	0.0000	91.5877	4.2577	1.5803	0.4681	0.3907	0.1383	0.0727	0.0600	0.0342	0.0100	0.0000	0.0000	0.0003	0.0001	0.0000	0.0000	99.9998	0.935627
12-11 BH	6/25/2012	0.33	19	0.7963	0.0000	93.8511	3.7449	0.8768	0.2674	0.1839	0.0988	0.0524	0.0618	0.0406	0.0166	0.0022	0.0002	0.0066	0.0001	0.0002	0.0000	99.9999	0.950785
12-11W BH	6/11/2012	0.76	19	0.9415	0.0000	92.7397	4.2221	1.1349	0.3341	0.2626	0.1281	0.0743	0.0792	0.0511	0.0219	0.0022	0.0002	0.0074	0.0001	0.0003	0.0003	100.0000	0.942155
21-11 BH	6/11/2012	0.83	19	1.2156	0.0000	93.7351	3.8083	0.8327	0.1713	0.1057	0.0367	0.0189	0.0186	0.0236	0.0218	0.0031	0.0003	0.0037	0.0004	0.0004	0.0039	100.0001	0.951619
32-11 BH	10/6/2011	0.07	11	3.1695	0.0000	85.6361	4.8457	2.5594	1.1795	1.1772	0.7327	0.4374	0.1702	0.0403	0.0228	0.0066	0.0033	0.0023	0.0074	0.0010	0.0085	99.9999	0.904711
41-11B BH	3/2/2012	0.97	?	1.0533	0.0000	92.7414	4.3634	0.7554	0.3824	0.2953	0.1407	0.0796	0.0849	0.0514	0.0255	0.0025	0.0125	0.0060	0.0048	0.0000	0.0010	100.0001	0.944076

D.6 Summary of Organic Compounds Detected in Produced Water Samples

Table SI D3. Summary of organic compounds detected in produced water by EPA Region 8 and Zymax (contractor to EPA[30]). PGPPXX are EPA sample identification codes.

	Tribal Pavillion 14-10 (PGPP01) EPA R8	**Tribal Pavillion 24-2 (PGPP04P) EPA R8**	**Tribal Pavillion 24-22 (PGPP04W) Zymax**	**Tribal Pavillion 33-10 (PGPP05) EPA R8**	**Tribal Pavillion 33-10 (PGPP05) Zymax**	**Tribal Pavillion 14-2 (PGPP06) EPA R8**	**Tribal Pavillion 14-2 (PGPP06) Zymax**
Volatile Analysis (mg/L)							
Methylene chloride	0.51 J	<50 U	NA	<0.025 U	NA	<0.025 U	NA
Benzene	8.02 J	860 J	2.053	0.306 J	0.379	3.02 J	1.953
Toluene	97.5 J	16800 J	11.329	0.774 J	1.284	9.07 J	7.288
Ethylbenzene	26.6 J	4410 J	0.632	0.476 J	0.579	0.542 J	0.262
m,p-Xylene	298 J	46000 J	11.513	2.18 J	3.684	4.76 J	4.292
o-Xylene	73.6 J	9430 J	2.64	0.797 J	1.307	1.37 J	1.1
1,2,4-Trimethylbenzene	31.6 J	8730 J	0.695	1.77 J	2.621	0.765 J	0.632
1,3,5-Trimethylbenzene	18.6 J	6250 J	0.465	0.818 J	1.566	0.414 J	0.366
n-Butyl Benzene	1.06 J	162 J	<0.005	0.218 J	0.179	<0.025 U	<0.050
sec-Butylbenzene	0.95 J	270 J	0.007	0.243 J	0.655	<0.025 U	0.062
tert-Butylbenzene	0.25 J	86 J	NA	<0.025 U	NA	<0.025 U	NA
n-Propyl Benzene	3.64 J	1290 J	0.13	0.198 J	0.803	0.07 J	0.11
Isopropylbenzene	11.4 J	948 J	0.542	0.202 J	3.427	0.058 J	0.337
p-Isopropyltoluene	1.64 J	334 J	NA	0.222 J	NA	<0.025 U	NA
Naphthalene	3.43 J	<200 U	<0.005 U	2.97 J	<0.050	0.21 J	<0.050
Adamantane	0.52 J	74 J	NA	0.305 J	NA	<0.025 U	NA
1,3-Dimethyl adamantane	0.46 J	<50 U	NA	0.488 J	NA	<0.025 U	NA
Semivolatile Analysis (mg/L)							
Phenol	NA	<2.0 U	NA	<2.0 U	NA	6.96 J	NA
2-Methylphenol	NA	<2.0 U	NA	<2.0 U	NA	7.76 J	NA
2,4-Dimethylphenol		<2.0 U	NA	<2.0 U	NA	5.00 J	NA
3 & 4-Methylphenol	NA	<2.0 U	NA	<2.0 U	NA	6.76 J	NA
Naphthalene	NA	30 J	NA	37.8 J	<0.050	<0.40 U	NA
2-Methylnaphthalene	NA	5.4 J	<0.005 U	110 J	<0.050	<0.40 U	NA
Adamantane	NA	47.2 J	NA	6.4 J	NA	<1.12 U	NA
1,3-Dimethyl adamantane	NA	9.8 J	NA	8.2 J	NA	<1.12 U	NA
Triethylene glycol	ND	ND	NA	ND	NA	17.8 (TIC)	NA

J – estimated concentration
U – below reporting limit
TIC – tentatively identified compound

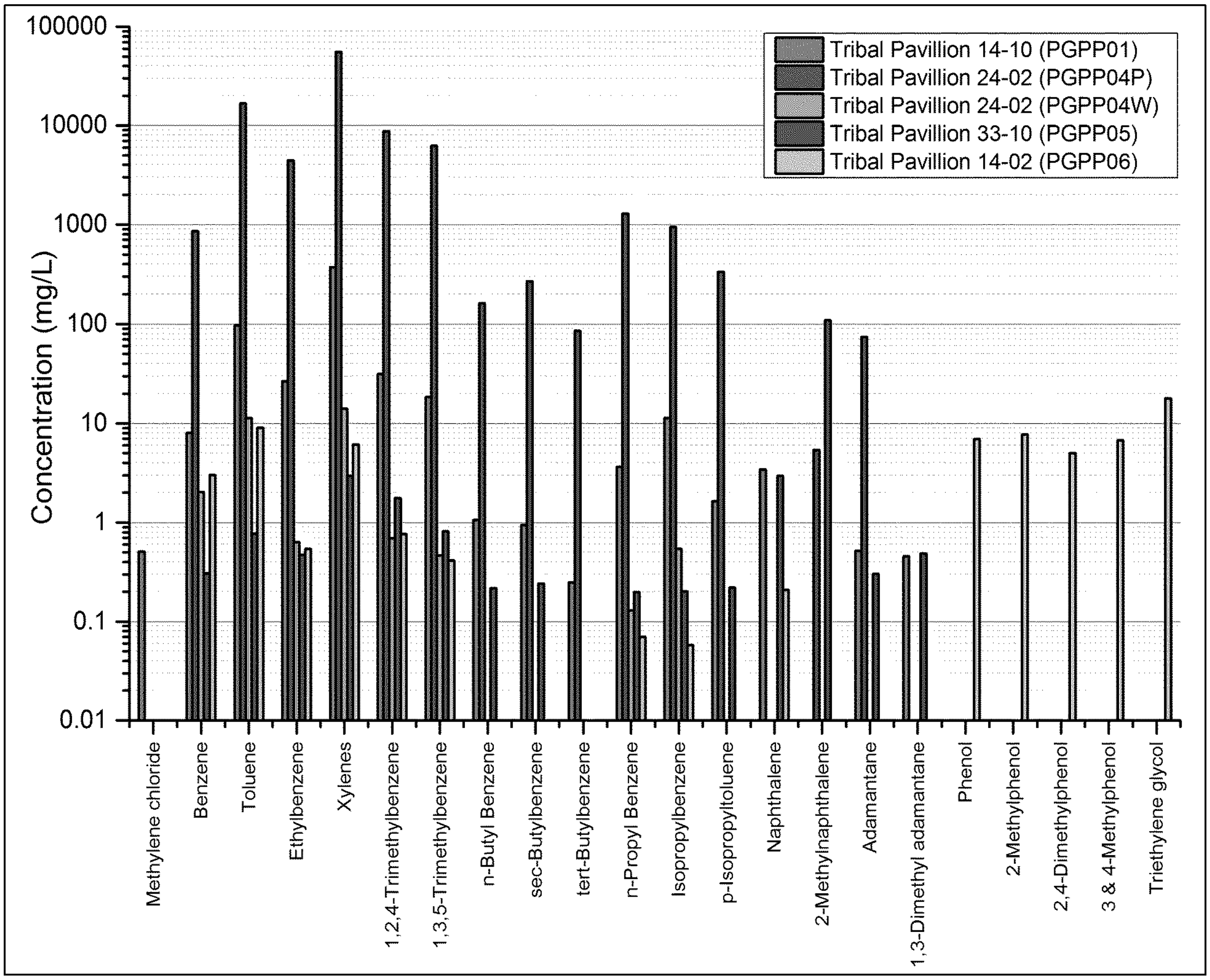

Figure SI D3. Organic compounds (volatile and semivolatile analyses) detected by EPA[30] in produced water at Tribal Pavillion 14-10 (PGPP01), Tribal Pavillion 33-10 (PGPP05) and Tribal Pavillion 14-02 (PGPP06) and product present with water at Tribal Pavillion 24-02 (PGPP04P). Triethylene glycol was a tentatively identified compound (gas chromatography area at least 10% as large as the area of the nearest internal standard and a mass spectrometry match quality greater than 90%).

E – EPA Monitoring Well Construction, Purging, and Sample Results

E.1 Monitoring Well Construction

In June 2010, EPA installed two monitoring wells, MW01 and MW02, using mud rotary drilling. Monitoring well construction schematics for MW01 and MW02 are provided in Figures SI E1 and SI E2, respectively. We modified schematics previously illustrated in EPA's draft report[27] to be more consistent with the prime contractor (Shaw Environmental) and subprime contractor (Boart-Longyear) and USGS (during redevelopment) daily logs. We typed and chronologically combined handwritten daily logs (not provided here) to gain a better understanding of activities during monitoring well construction.

Water Used for Drilling Mud

Boart-Longyear used a water supply truck to transport municipal water from Riverton, WY to mix bentonite for MW01 and MW02. This truck was not used for any other purpose. Water was not stored in tanks prior to use. Municipal water was sampled by the City of Riverton on 7/26/2010 (the same time as drilling). It is unlikely that water used to mix drilling mud impacted analytical results at MW01 and MW02 for the following reasons. (1) No volatile petroleum hydrocarbons were detected. The reporting limit for benzene, toluene, ethylbenzene, o-xylene, m, p-xylenes, naphthalene, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene was 0.50 μg/L. (2) With the exception of chlorine disinfection products, choroform and trihalomethanes, detected at 2.3 and 2.7 μg/L respectively, no other volatile organic compounds were detected. Choroform and trihalomethanes were not detected in aqueous samples from MW01 and MW02 indicating loss of these compounds via volatilization and/or degradation during drilling. (3) No semivolatile organic compounds were detected. (4) No additives (e.g., biocides) were added to the water during transport and use.

Additives Used for Drilling Mud

Boart-Longyear used a number of additives (Table SI E1) in water-based drilling mud to avoid heaving of shale and a product, Aqua-Clear PFD, to facilitate removal of mud after drilling. MSDSs indicated that: (1) Quik-Gel was comprised of bentonite (60%), crystalline silica quartz (1-5%), crystalline silica cristobalite (0-1%), and crystalline silica tridymite (0-1%); (2) EZ-Mud Gold contained "no hazardous substances"; (3) Quik-Trol Gold was a cellulose derivative with a 60-100% polysaccharide concentration; (4) dense soda ash was 100% sodium carbonate (Na_2CO_3); (5) Penetrol contained 1-5% of diethanolamine and 10-30% coco diethanolamide; and (6) Aqua-Clear contained 30-60% of an anionic polyacrylamide.

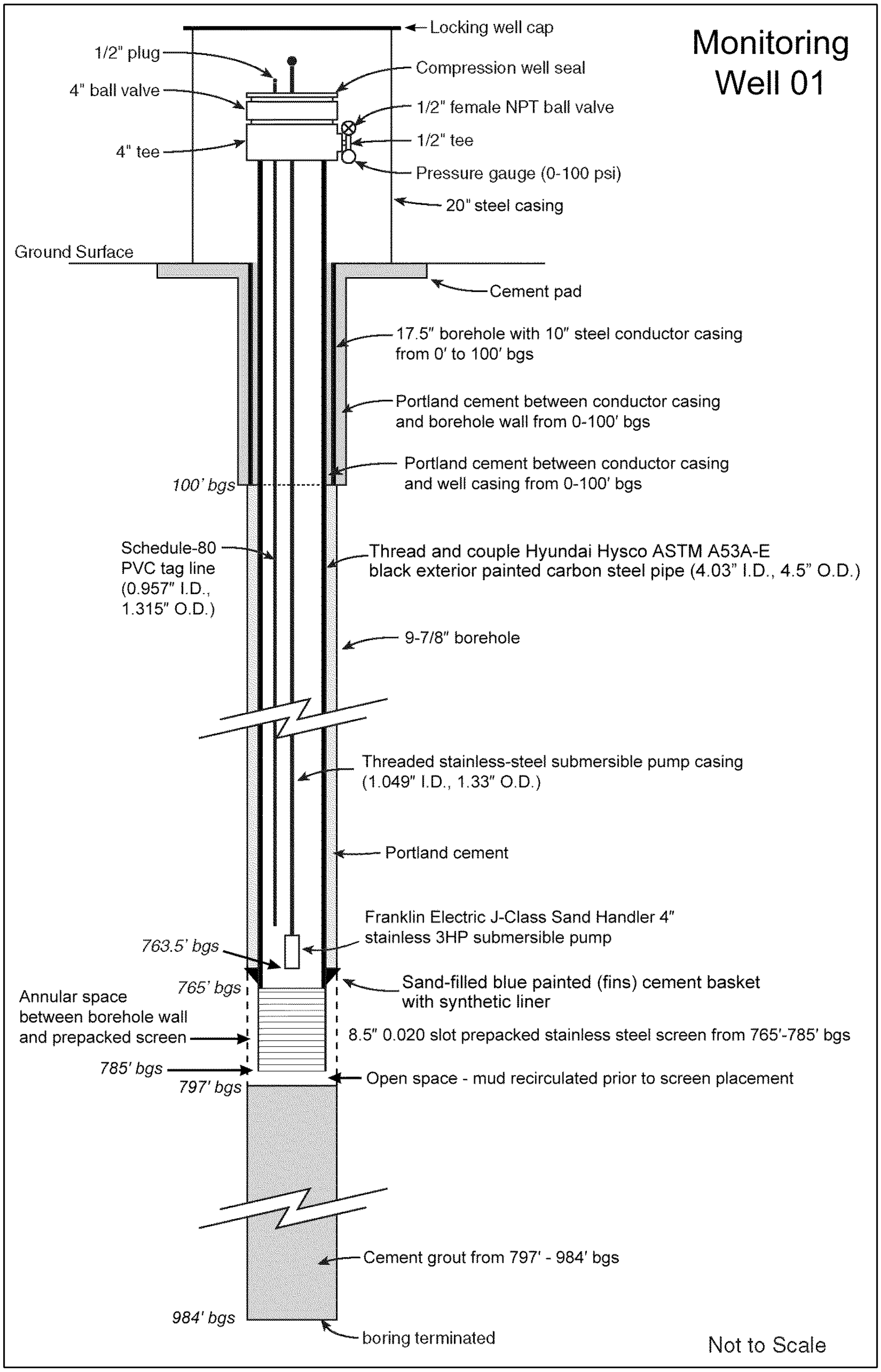

Figure SI E1. Well schematic for MW01 modified from EPA[27]

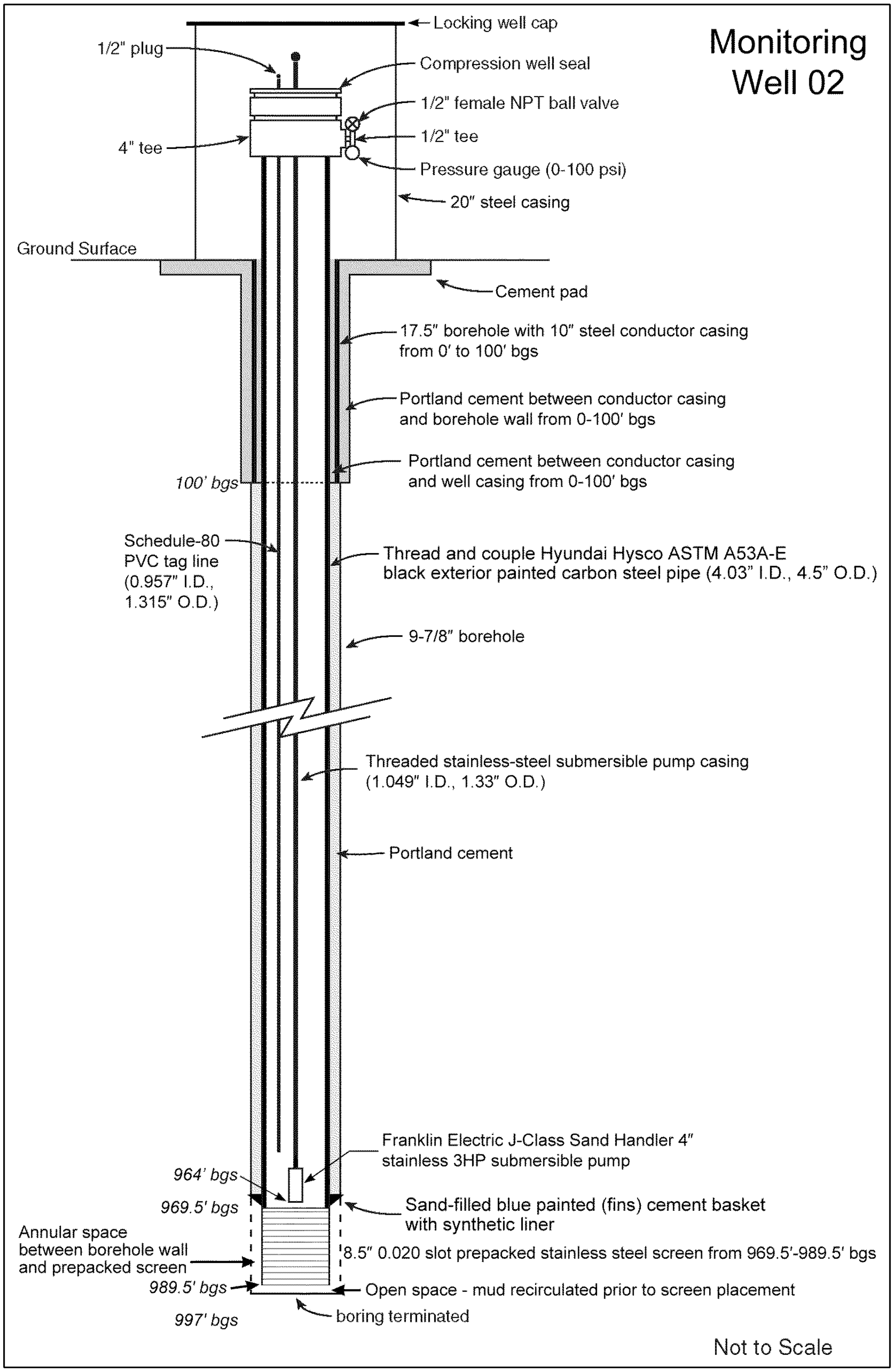

Figure SI E2. Well schematic for MW02 modified from EPA[27]

Table SI E1. Summary of products used for mud rotary drilling, mass ratios of product use, analyses of aqueous extracts of products, and maximum concentration of detection in MW01 and MW02.

Parameter	Aqua-Clear PFD	Penetrol	EZ-Mud Gold	Dense Soda Ash	Quik-Gel	Quik-Trol Gold	MW01	MW02
Manufacturer	Haliburton	Haliburton	Haliburton	OCI Chemicals		Haliburton	-----	-----
Specified use of additive	Dispersant – assist mud removal		shale/clay stabilizer		bentonite	clarifier	-----	-----
form	liquid	liquid	solid	solid	solid	solid	-----	-----
mass ratio in extract	1:20	1:20	1:100	1:100	1:100	1:100	-----	-----
mass ratio in water used for mud or development at MW01	1:467	1:2347	1:236	1:1211	1:36	1:634	-----	-----
Normalization factor for MW01	23.4	117.6	2.36	12.1	0.36	6.34	-----	-----
mass ratio in water used for mud or development at MW02	1:467	not used	1:1252	not used	1:36	1:1252	-----	-----
Normalization factor for MW02	23.4	-----	12.5	-----	0.36	12.5	-----	-----
Concentration in Aqueous Extract and Estimated Concentration in Aqueous Portion of Drilling Mud in Parenthesis Upper and Lower sets of concentrations refer to MW01 and MW02, respectively							**Maximum Concentration in Monitoring Wells**	
pH of aqueous extract of product	7.96	8.51	6.64	11.2	8.35	NA	11.9	12
Specific Conductance (mS/cm)	13.3 (0.57) 13.3 (0.57)	0.47 (0.004) not used	0.24 (0.10) 0.24 (0.02)	15.5 (1.28) not used	0.20 (0.56) 0.20 (0.56)	NA NA	3.265	3.812
DOC (mg/L)	1640 (70.2) 1640 (70.2)	1500 (12.78) not used	388 (164) 388 (31.0)	0.58 (0.05) not used	2.11 (5.86) 2.11 (5.86)	NA NA	9.43	19.7
Cl (mg/L)	214 (9.16) 214 (9.16)	85 (0.72) not used	2.22 (0.94) 2.22 (0.18)	7.03 (0.58) not used	ND ND	NA NA	23.3	466
SO_4 (mg/L)	121 (5.18) 121 (5.18)	597 (5.09) not used	ND ND	ND ND	3.53 (9.81) 3.53 (9.81)	NA NA	428	81.8
K (mg/L)	0.40 (0.02) 0.40 (0.02)	0.63 (0.005) not used	1.16 (0.49) 1.16 (0.09)	0.12 (0.01) not used	0.09 (0.25) 0.09 (0.25)	NA NA	54.9	44.0
acetone (µg/L)	ND ND	ND ND	ND ND	NA NA	NA NA	NA NA	79.5	1460
tert-butyl alcohol (µg/L)	ND ND	ND ND	ND ND	NA NA	NA NA	NA NA	<5.0	6120
isopropanol (µg/L)	85(J) (3.64) 85(J) (3.64)	43(J) (0.37) not used	27(J) (11.4) 27(J) (2.16)	NA NA	NA NA	NA NA	212	862
ethanol (µg/L)	59(J) (2.53) 59(J) (2.53)	58(J) (0.49) not used	ND ND	NA NA	NA NA	NA NA	<1.00	7.49
benzene (µg/L)	ND ND	ND ND	ND ND	NA NA	NA NA	NA NA	<0.50	246
toluene (µg/L)	ND ND	ND ND	ND ND	NA NA	NA NA	NA NA	<0.50	677
ethylbenzene (µg/L)	ND ND	ND ND	ND ND	NA NA	NA NA	NA NA	<0.50	101
xylenes (µg/L)	ND ND	ND ND	ND ND	NA NA	NA NA	NA NA	<0.50	1063
trimethylbenzenes (µg/L)	ND ND	ND ND	ND ND	NA NA	NA NA	NA NA	<1.00	265
naphthalene	ND ND	2.00 (0.02) not used	ND ND	NA NA	NA NA	NA NA	<1.00	7.2
ethylene glycol (µg/L)	ND ND	ND ND	ND ND	NA NA	NA NA	NA NA	<5000	<5000
diethylene glycol (µg/L)	ND ND	ND ND	ND ND	NA NA	NA NA	NA NA	60.0	1610

ND – not detected
NA – not analyzed
J – estimated (below the level of quantification)

EPA stored samples of products used for drilling in glass mason jars containing lids, transported products with a chain of custody form by vehicle to its Office of Research and Development (ORD) laboratory in Ada, OK, and archived products in a refrigerator at 4°C prior to extraction with water. Analysis for organic compounds were not conducted on water extracts of Quik Gel and Quik-Trol Gold due to the gel nature of extracts and concern of analytical equipment damage. The dissolved organic carbon of dense soda ash was only 0.58 mg/L and based on MSDS, was not expected to be a source of organic compounds. EPA's analysis of extracts is noteworthy in that we could find no other published studies in which an organization collected and analyzed samples of products used for drilling mud during installation of monitoring wells.

With the exception of dense soda ash, the pH of extracts were well below that maximum pH levels (~12) observed in MW01 and MW02. Dense Soda Ash was not used at MW02. Alkalinity of soda ash is dominated by carbonate not hydroxide as observed in MW01. The pH of drilling mud in which dense soda ash was mixed in MW01 varied between 8 and 9 standard units. Thus, additives had no effect on pH measurements during sampling at monitoring wells.

To estimate expected concentrations of compounds in additives in water used for drilling mud, we normalized aqueous extraction concentrations by a normalization factor defined by

$$Normalization\ Factor = \frac{mass\ ratio\ in\ water\ used\ for\ drilling\ mud\ or\ well\ development}{mass\ ratio\ in\ aqueous\ extract}$$

For instance, the mass ratio of the water extract of Aqua-Clear PFD was 1:20 while use in water used for well development was 1:467 resulting in a normalization factor of 1/20 divided by 1/467 or 23.4. Results are provided in Table SI E1.

At MW02, Boart-Longyear used 21 sacks or 1,050 pounds of Quik-Gel for drilling. The initial mass of bentonite used at MW01 was not provided in the logs. However, the mass of bentonite used at MW01 is expected to be similar to MW02 given that the target depth (almost 305 m or 1,000 feet) was the same at both wells. A log entry on 6/11/10 at 10:20 from MW02 indicates that 17,000 L (4,500 gallons) of water was used to mix mud for drilling at this well. The volume of water used to mix mud at MW01 was not specified in the drilling logs. However, both wells were drilled to the same depth under the same subsurface conditions so the volume of water used at MW01 would be expected to be similar to that used at MW02.

Concentrations of potassium in monitoring wells were well below concentrations and normalized concentrations in extracts. The extract and normalized concentration of chloride in Aqua-Clear PFD was lower and far lower than detected in MW02. During the Phase V sampling event, acrylamide was added to the target list of analytes and was not detected in any samples from MW01 and MW02 (< 10 µg/L)[33] indicating that any compounds associated with Aqua-Clear PFD were removed during well development. With the exception of naphthalene detected at 2.0 µg/L in a Penetrol extract (normalized concentration of 0.02 µg/L in MW01), petroleum hydrocarbons were not detected in extracts. The maximum concentrations and normalized concentration of isopropanol in extracts 85 was 11.4 μg/L, respectively compared to 212 and 862 μg/L at MW01 and MW02, respectively. BTEX compounds (benzene, toluene, ethylbenzene, and xylenes) were not detected in extracts but were detected at MW02.

EPA collected composite samples of cuttings and sent them with a chain of custody form to TestAmerica Laboratories in Denver, Colorado for Toxic Characteristic Leaching Procedure (TCLP). Samples were analyzed for TCLP volatile organic compounds using gas chromatography-mass spectrometry (GC-MS) in accordance with EPA SW-846 Methods 1311/8260B, for TCLP semivolatile organic compounds (GC-MS) in accordance with EPA SW-846 Methods 1311/8270C, for TCLP metals in accordance with EPA SW-846 Methods 1311/6010B, and for TCLP mercury in accordance with EPA SW-846 Methods 1311/7470A. Acetone, toluene, and m & p-xylene were detected in one sample at 6.9, 0.63, and 1.0 μg/L, respectively, concentrations far lower than that detected in MW02. Considering all these factors, it is unlikely that additives used for drilling mud impacted sample results in MW01 and MW02.

Well Development

Well development criteria stated in EPA's Monitoring Well Installation were as follows: water samples < 10 Nephelometric Turbidity Units (NTUs), or 3 purge volumes if < 10 NTU prior to attainment of 3 purge volumes, or 5 purge volumes if < 10 NTU is not achieved after three purge volumes. Daily logs indicate that 33,320 L (8815 gallons) or 24.5 purge volumes of water was removed from MW01 prior to the first round of sampling in October 2010 in which turbidity of sampled water was 7.5 NTUs. Hence, well development criteria were met at MW01. MW02 was a low yield well. Daily logs indicate that 5,760 L (1524 gallons) or 3.2 purge volumes of water was removed prior to the first sampling event in October 2010 in which the turbidity of sampled water was 24 NTUs. Elevated turbidity was caused by gas flow and pump cavitation due to gas flow. For instance, during the Phase V sampling event, during which removal of 5 purge volumes had been attained, turbidity was measured at 4.5 NTUs prior to pump cavitation and 15.7 NTUs after pump cavitation. Thus, well development criteria was ultimately achieved for both monitoring wells. Turbidity is not expected to have any impact on analysis of organic compounds nor on inorganic analyses since samples were filtered.

Steel Well Casing

Boart-Longyear used thread and couple Hyundai HYSCO ASTM A53A-E steel pipe for well casing at both MW01 and MW02. A 6.1 m (20 ft) stainless-steel pre-packed screen was attached to casing via flush threads. EPA specified the use of metal casing to ensure sufficient tensile strength, especially at joints during well placement. The tensile strength of steel and stainless-steel joints is over an order of magnitude greater than polyvinyl chloride (PVC) joints. The WYDEQ (Well Construction Standards, Chapter 11, Part G) explicitly allows for the use of ASTM A53 steel casing for well construction.

Materials used for well casing and screens can impart both negative and positive bias in detection and quantification of target analytes. Steel is an alloy consisting primarily of iron (Fe). The maximum allowable concentrations of manganese (Mn), copper (Cu), nickel (Ni), chromium (Cr), molybdenum (Mo), and vanadium (V) in ASTM A53A-E[38], steel pipe are 0.95, 0.40, 0.40, 0.15, and 0.08% by weight, respectively. Houghton and Berger[39] noted a slight enrichment of Fe and Mn in water from wells constructed of steel compared to wells constructed from PVC and acrylonitrile-butadiene-styrene (ABS).

Interaction can also occur with stainless steel. Hewitt[40] conducted static and dynamic (flushing) experiments on PVC, PTFE, stainless steel-SS-304 (SS-304), and stainless steel-316 (SS-316) casing materials in glass cylinders containing well water with low dissolved oxygen (DO) (< 0.5 mg/L) and observed corrosion of both SS-304 and SS-316 during testing (pH 7.6 - 7.8). Low concentrations of Cu, Cr, and Ni leached from both virgin SS-304 and SS-316. However, leaching of Cr and Ni increased significantly with corrosion. Hewitt[40] observed that concentrations of cadmium (Cd), Fe, and lead (Pb) decreased indicating sorption to casing. Hewitt[40] stated that reduction of Fe was consistent with precipitation of $Fe(OH)_2$ and that iron oxides provided active exchange sites for sorption of these elements.

In an EPA report, Aller et al.[41] state that potentially corrosive conditions exist for steel in ground water having low pH (< 7) and elevated DO (> 2 mg/L), hydrogen sulfide (H_2S) (> 1 mg/L), TDS (> 1000 mg/L), CO_2 (> 50 mg/L), and Cl (> 500 mg/L) and that use of steel is not considered prudent in most natural geochemical environments. Subsequent to well development, purged water from MW01 and MW02 was largely devoid of dissolved oxygen during Phase III, IV, and V sampling events with a pH level in excess of 11 standard units.

In its Draft RCRA Ground-Water Monitoring Guidance, EPA[42] states that use of carbon steel, low-carbon steel, and galvanized steel is not recommended for monitoring well construction in most natural geochemical environments and use of Type 304 and Type 316 stainless steel is unsuitable for use when monitoring for inorganic constituents. In an EPA Issue Paper, Pohlmann and Alduino[43] state that when corrosion is a concern, use of stainless-steel casing is not appropriate. In another EPA Issue Paper, Llopis[44] states that if samples are to be analyzed for metals, metal casing of any type should not be used. Thus, when installing monitoring wells to sample both metals and organic compounds, there are no consistent regulatory guidelines on use of materials for well casing.

During the week of April 30th, 2012 (after cessation of Phase V sampling), a drilling crew from USGS removed the 3 HP submersible pump in MW02, examined the casing and screen with an optical televiewer, and attempted to redevelop the well. The optical televiewer indicated that the screen and casing was intact. During re-development, sediment was removed from the base of the screen. Four sub-samples of the material were sent to Gulf Coast Accutest Laboratories for analysis of metals with the following range of results: aluminum (1950-2720 mg/kg), antimony (2.5-3.4 mg/kg), arsenic (3.3-10 mg/kg), cadmium (<0.26-2.1 mg/kg), chromium (79.9-108 mg/kg), copper (168-719 mg/kg), lead (16.2-56.3 mg/kg), nickel (49.4-64.9 mg/kg), selenium (<0.26 mg/kg), and titanium (52.2-80.5 mg/kg). Results of metals analysis indicated that this sediment was either scrapings from steel pipe or a combination of scrapings from steel pipe and corrosion material removed from steel casing during development and re-development activities. During the Phase V sampling event, dissolved concentrations of Cd, Pb, Fe, Mn, Cu, Ni, Cr, Mo, and V at MW01 and MW02 were less than reporting limits at 1.0, 1.0, 67, 14.0, 2.0, 1.0, 2.0, 17, and 10 μg/L, respectively. Hence, the use of metal casing and presumed corrosion in areas of swabbing did not impart a positive bias on sample results for metals at MW01 and MW02.

However, corrosion can impact measured pH. Marsh and Lloyd[45] attributed elevation of pH in steel casing to corrosion and precipitation reactions mediated by carbonic acid and hydrogen sulfide. In both reactions, hydrogen ion is consumed and hydrogen gas is produced. During purging of capped artesian monitoring wells, Marsh and Lloyd[45] observed that pH decreased abruptly (e.g., pH 8.8 to pH 7.2) after a short period of time in wells where water flowed through the entire length of casing to the surface. However, there was little variation in pH in monitoring wells having sampling tubes placed within screened intervals. In contrast to observations by Marsh and Lloyd[45], pH reduction in MW01 during purging was gradual with the trend of pH reduction unrelated to removal of stored casing water. Thus, corrosion was not a causative factor of elevated pH at MW01 and MW02.

Black steel ASTM A53 pipe has a lacquered outside finish as opposed to a bare or galvanized finish. Manufactures coat the outside of steel pipe with a black paint to prevent rust and corrosion. However, sampled water does not come in contact with the exterior of well casing. Photographs (DiGiulio et al.[27]) of casing indicate no apparent mill varnish or visual signs of oil and grease prior to or after casing decontamination procedures. Thus, it is unlikely that black varnish on the exterior of metal casing was responsible for detection of organic compounds in MW01 and MW02. Also, a non-hydrocarbon based pipe dope (Jet Lube WellGuard) was used on well casing joints. Thus, well casing is not responsible for detection of hydrocarbons in monitoring wells.

During conventional monitoring well construction, a bentonite slurry seal is typically placed on top of a primary or secondary filter or sand pack to limit the downward movement of a cement-based grout (ASTM[46], EPA[42]). As documented in the draft[47] and final[48] workplans for well installation, this method of well completion was planned for both MW01 and MW02. However, as documented in field logs, during drilling, Shaw and Boart-Longyear advised EPA against the use of a conventional screen and sand pack for well completion at MW01 and MW02 due potential difficulty in sand pack placement (displacement of high density drilling mud with sand) and well development (removal of mud from sand pack). Shaw and Boart-Longyear recommended the use of pre-packed screens and cement baskets (filled with sand at the surface) in lieu of conventional screens and sand packs. EPA concurred with this approach for well completion.

An additional reason for not utilizing a bentonite slurry as a sealing agent is the presence of localized upward hydraulic gradients. Localized upgradient gradients are documented in the Wind River Formation[26], was present in a domestic well during the Phase II sampling event[27], and was observed at 4 production wells during Bradenhead testing conducted by Encana in 2012. A cement-bentonite grout may not set when a strong uplift is present[49,50]. Under these conditions, pumped bentonite grout never sets up to anything more than thick paste[51]. In addition, a bentonite grout backfill would not have been volumetrically stable with overlying cement application since the specific gravity of cement grout was greater than that of the bentonite slurry. A cement-based grout has the widest regulatory acceptance and is the most commonly used to seal the annular space of deep wells[46] such as MW01 and MW02.

Cement Baskets

Cement baskets with blue metal "fins" and a rubber or synthetic liner were threaded to stainless-steel casing containing the stainless-steel pre-packed screens. The joint attaching stainless-steel casing to stainless-steel screen was reinforced with spot welding to increase the structural integrity of the joint. This was necessary to properly position the screen into the borehole prior to descent to target depth. McKay electrodes were used for welding. The MSDS for this product did not indicate the presence of organic compounds.

The composition of the cured (not applied in the field) blue paint on metal springs and rubber liner were not specified by EPA. Organic compounds in cured paint exist in cross-linked polymer matrix and generally considered resistant to leaching[52]. However, little is published on leaching of organic compounds from cured paint. Alben et al.[53] studied leaching of organic contaminants from epoxy-coated flat steel panels, with emphasis on the rate of leachate production and leachate composition. Methyl isobutyl ketone (MIBK), o-, m-, and p-xylene represented a major portion (51%) of leachate from the epoxy coating. These findings were supported by field studies indicating the presence of MIBK and xylenes in water from the effluent from 2 of 3 storage tanks that were monitored one month after application of an epoxy coating[53]. The extent of leaching of organic contaminants from epoxy resin linings was found to be strongly dependent on the duration of the curing process with longer curing periods producing more stable linings.

It is unlikely that blue paint on cement baskets was a causative factor for detection of 2-butoxyethanol and other organic compounds detected in MW01 and MW02 because of the following reasons. (1) MIBK and xylenes were not detected in MW01. (2) There was a low surface area for aqueous exposure (<0.05 m^2), a low retention time in the screened interval during sampling especially at MW01 (20 minutes) during phase IV and phase V sampling events, and a large number of number of screen exchanges prior to sampling (especially at MW01 prior to the Phase V sampling event with > 200 exchanges).

Cement Placement

High pH levels (~12) were observed during purging and sampling at MW01 and MW02 during Phase III, IV and V sampling events. Daily logs do not indicate that the tremie pipe for cement placement was placed directly through cement baskets or that cement was pumped directly into screened intervals at MW01 and MW02. At MW01, circulation was lost on 7/26/10 while drilling through a sandstone unit from 655 to 725 feet bgs and as shown on an electric log and borehole log descriptions. The caliper log indicates that a washout occurred at 715 feet bgs. Thus, some cement likely intruded into the formation above the screened interval at 765-785 ft bgs.

At MW01 and MW02, cement was pumped to target depths using a tremie pipe and placed in lifts to avoid buildup of pressure above the basket potentially causing basket collapse. At MW01, sand was added to the sand basket prior to setting the casing and screen in the borehole. The screen was subsequently hung and a cement plug was placed from 228.0-233.2 m (748-765 ft) bgs on 8/5/10 and left to set up overnight. The cement was tagged at 748 feet. Cement placement resumed the following day with 14 yd^3 of Portland cement on top of the set plug.

At MW02, more cement, approximately 76-189 L (20 – 50 gallons) was utilized than expected when grouting above the cement basket. Based on a review of daily logs, the most likely explanation for this discrepancy is that the screened interval placement at MW02 was lower than reported by the driller or subcontractor. During the week of April 30th, 2012, a drilling crew from USGS removed the submersible pump in MW02, examined the casing and screen with an optical televiewer, and attempted to redevelop

MW02. A member of the crew stated that tagging tape indicated that the base of the screen of MW02 was at 989.5 ft not 980.0 ft bgs as expected. This measurement was checked a second time and the measurement tape was checked for accuracy. If the screen interval was in fact 9.5 ft lower than indicated on the driller's logs, then additional cement would have been necessary to reach the top of the cement basket overlying the screen. Threads on casing collars were visible at all joints located above the water table surface (e.g., pieces of pipe are not threaded flush at their ends). Neither cement nor mud was visible in the joints. An extra one to two inches at each couple would result in the well screen placed 4 - 8 feet deeper than expected or close to 9.5 ft as observed. Given a borehole diameter of 9.9 inches, 30 and 50 gallons of cement is equivalent to approximately 9.5 and 15.9 linear feet of cement which is close to 10.5 linear feet of distance between tagged cement at 958 ft and the top of the screened interval at 968.5 ft bgs.

E.2 Purging at MW02

MW02 is a low flow monitoring well. During the Phase III, IV, and V sampling events, purging at MW02 was repeatedly interrupted by pump cavitation. Low flow may be due to low relative aqueous permeability due to gas flow or insufficient removal of drilling mud during well development. In May 2012, USGS unsuccessfully attempted to redevelop MW02 via swabbing[54].

During the Phase V sampling event, pre- and post-purge samples were collected at MW02 to assess potential reduction in dissolved gas and VOC concentrations due to gas flow in casing[55,56]. MW02 was repeatedly purged over a 6-day period (Figure SI E3) to remove one borehole volume (2000 L) of water and subsequently sampled when sufficient water was present to support analysis per EPA guidelines[42,57].

USGS[58] has a "rule of thumb" recommendation to avoid sampling a well that has not recovered to within 90% of its static water level within a 24-hour period and has had less than one borehole volume of water removed during purging. Based on the slow recharge rate of MW02, USGS elected not to physically participate in sampling MW02[54]. Instead, EPA collected samples at MW02 and provided them to USGS for analyses at a commercial laboratory[59] similar to MW01[60]. Recovery occurs more rapidly in a low yield well having a low blank casing to screened interval ratio typical of shallow wells. MW02 consisted almost entirely of blank casing. Recovery to 90% of static water level required recovery of 202 m of water level rise in a 24-hour period.

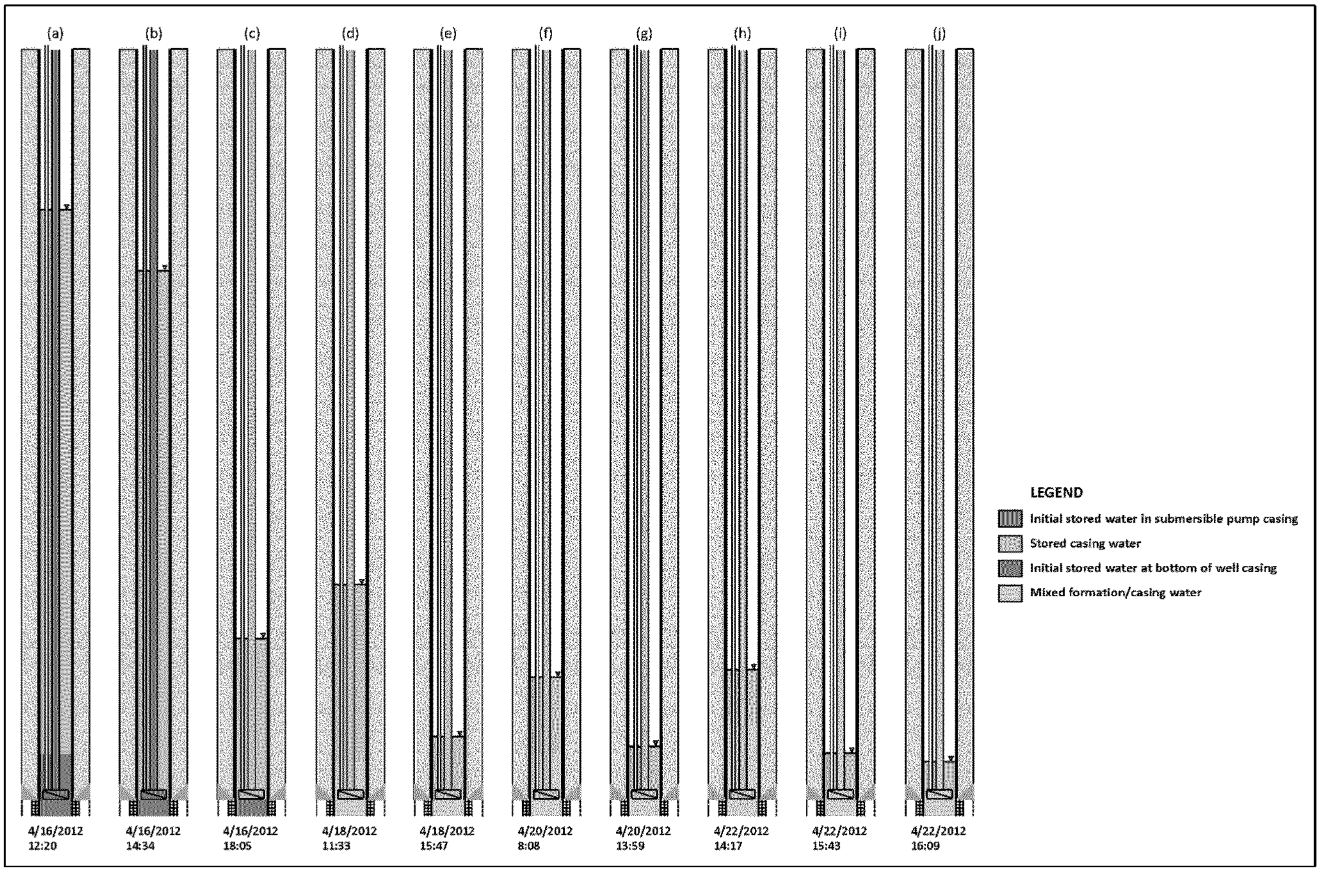

Figure SI E3. Illustration of purging and sampling sequence (date and times provided) at MW02 for Phase V sampling event. Vertical scale reflects relative lengths of screen, casing, and water levels: (a) Pre-purge condition. Dark gray color denotes water stored in submersible pump casing remaining from the Phase IV sampling event. Mustard colored water denotes water in casing from recovery following the Phase IV sampling event and targeted for removal during the first sample set. Light gray colored water denotes stored casing water from recovery during Phase III and IV sampling events. (b) Water is removed (170L or 45 gal) from the submersible pump casing, replaced with water from above the pump inlet, and sampled. (c) Water above pump inlet is removed (964 L or 255 gal). (d) Recovery occurs (132 L or 35 gallons). Light blue color indicates mixing of water initially present in the screened interval with incoming formation water. (e) Water above pump inlet removed (491 L or 130 gal) from casing. (f) Recovery occurs (167 L or 44 gallons) with further mixing of water in the screened interval. (g) Water above pump inlet removed (215 L or 57 gal). (h) Recovery occurs (189 L or 50 gal) with further mixing of water in the screened interval. (i) Water in submersible pump casing is removed (165 L or 45 gal) and replaced with mixed casing/formation water. (j) Mixed casing/formation water is sampled. Total volume of water removed during the Phase V sampling event prior to collection of the second sample was 2011 L or 532 gal equivalent to 1.04 borehole volumes.

E.3 Purging and Wellbore Model Development at MW01

In the commonly used "well volume' approach to purging, three casing volumes are typically removed prior to sampling[58]. It is assumed that water in blank casing is uniformly removed during purging prior to sampling. However, little or no mixing of water in blank well casing actually occurs above a pump inlet upon stabilization of drawdown[61,62]. Placement of a submersible pump inlet directly above a screened interval, as was done at both MW01 and MW02 (Figures SI E1 and SI E2), minimizes collection of purge water requiring disposal and takes advantage of flow mechanics to ensure minimal or no contact with blank well casing during sample collection.

EPA[63] used a wellbore plug flow model based on flow rate and drawdown to evaluate percent collection of casing and formation water as a function of purge volume and time at MW01. To evaluate removal of dissolved solids in well casing and better evaluate collection of formation water as a function of purge volume, we modified EPA's approach to include mixing in a screened interval. Mixing in a well screen causes a slower transition from casing water to formation water than would occur from plug flow alone.

Prior to commencement of purging, we assume that the concentration of a solute in a screened interval, pre-packed screen, and annular space between the pre-packed screen and borehole wall has an initial vertically integrated initial concentration (C_0) and water in blank casing above the screened interval has an initial vertically integrated initial solute concentration (C_C) (Figure SI E4a). Depending upon variation between C_0 and C_C, differentiation of screen and casing concentrations results in complex hypothetical concentration profiles in the sampling train at the start of purging which dissipate rapidly upon removal of one casing or borehole volume (simulations not illustrated).

At the commencement of purging, water is removed from submersible pump casing. Combined downward and upward flow occurs in blank casing above and below the pump inlet respectively (Figure SI E4b) as drawdown occurs in the well. We assume that water in submersible pump and well casing undergoes unmixed plug flow. In the screened interval, radial flow occurs from the surrounding formation and mixes with water initially in the borehole and screen. The mass balance mixing model in the screened interval used is similar to that used by others[64]. This mixed water then undergoes upward flow in the casing to the pump inlet (Figure SI E4b). As drawdown stabilizes, all of the water entering the pump inlet is from the formation (Figure SI E4c). Sampling then occurs after water level recovery (Figure SI E4d) to ensure that all water entering the inlet and flowing to the sampling train is directly from the formation in the event of a slight change in pumping rate due to pump operation. Without allowing for some level of recovery above the pump inlet, a slight and unintentional increase in pumping rate could cause a small but measureable increase in drawdown and again induce some degree of mixing between formation and casing water. This procedure was followed by EPA at MW01 during all sampling events.

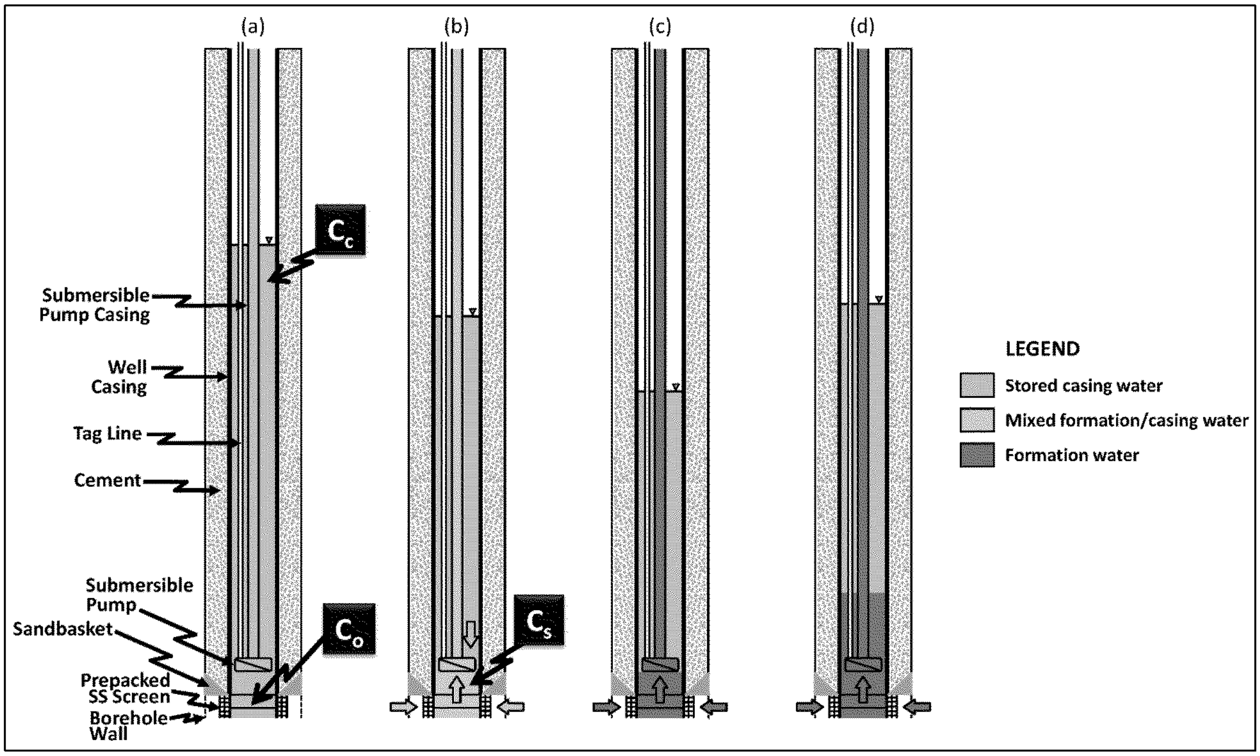

Figure SI E4. Plug flow - screen mixing model to support evaluation of purging: (a) Prior to purging, the concentration of a solute in the screened interval (and surrounding borehole) and overlying casing is equal to an initial value C_0 and a constant concentration C_C respectively. (b) During drawdown at commencement of purging, both downward and upward plug flow is assumed in casing above and below a pump inlet, respectively. Radial flow occurs from the surrounding formation with subsequent mixing of formation water and water initially in the borehole and screen. (c) As drawdown stabilizes, all of the water entering the pump inlet is directly from the formation. (d) Water level recovery is allowed to occur to ensure that all water entering the inlet is directly from the formation in the event of slight water level perturbation during pumping.

Model development is summarized as follows. Casing volume (V_C) [L^3] is defined as:

$$V_C = \frac{\pi}{4B}\left[L_{WC}D_{ID-WC}^2 - L_{PC}\left(D_{OD-PC}^2 - D_{ID-PC}^2\right) - L_{TL}\left(D_{OD-TL}^2 - D_{ID-TL}^2\right) - L_{SP}D_{OD-SP}^2 + L_{PC*}D_{ID-PC}^2\right]$$

L_{wc} = length of water column in well (depth to base of screen - depth to static water level) [L]
L_{PC} = length of submerged pump casing (depth to top of pump - static water level) [L]
L_{PC*} = length of submersible pump casing to the surface (static water level) [L]
L_{TL} = length of submerged tag line (depth of tag line - static water level) [L]
L_{SP} = length of submersible pump [L]
D_{ID-WC} = inside diameter of well and screen casing (cm) [L]
D_{OD-PC} = outside diameter of submersible pump casing [L]
D_{ID-PC} = inside diameter of submersible pump casing [L]
D_{OD-TL} = outside diameter of tag line [L]
D_{ID-TL} = inside diameter of tag line [L]
D_{SP} = diameter of submersible pump [L]
B = Dimensional constant (units of length and volume are in cm and liters respectively, B = 1000).

The term $L_{WC}D_{ID-WC}^2$ accounts for water storage in casing, including the screened interval, without modification for internal components. The term $L_{PC}\left(D_{OD-PC}^2 - D_{ID-PC}^2\right)$ accounts for the volume of submerged submersible pump casing material. The term $L_{SP}D_{OD-SP}^2$ accounts for the volume of the submersible pump. The term $L_{PC*}D_{ID-PC}^2$ accounts for water storage in the submersible pump casing above the static water level. Valves within submersible pump casing allowed water in casing to extend to land surface. Borehole volume VB [L^3] is defined as:

$$V_B = V_C + \frac{\pi}{4B}\left[\phi L_{SS}\left(D_{OD-PP}^2 - D_{OD-WC}^2\right) + L_{SS}\left(D_{BH}^2 - D_{OD-PP}^2\right)\right]$$

L_{SS} = length of stainless-steel pre-packed screen [L]
D_{OD-WC} = outside diameter of steel well casing [L]
D_{OD-PP} = outside diameter of pre-packed screen [L]
D_{BH} = diameter of borehole [L]
ϕ = effective porosity of pre-packed screen (assumed 0.4).

The term $\phi L_{SS}\left(D_{OD-PP}^2 - D_{OD-WC}^2\right)$ accounts for water storage in the pre-packed screen. The term $L_{SS}\left(D_{BH}^2 - D_{OD-PP}^2\right)$ accounts for water storage in the annular space between the pre-packed screen and borehole wall. During drawdown, the relative concentration of a solute entering a sampling train at the surface can be expressed by:

$$\left(\frac{C_P}{C_F}\right)_i = \frac{\frac{C_C}{C_F}\left(\frac{Q_{AP}}{Q_T}\right)_i + \left(\frac{C_{BP}}{C_F}\right)_i\left(\frac{Q_{BP}}{Q_T}\right)_i}{\left(\frac{Q_{AP}}{Q_T}\right)_i + \left(\frac{Q_{BP}}{Q_T}\right)_i}$$

C_P = concentration exiting the submersible pump casing at the surface at time increment i [ML^{-3}]
C_F = constant concentration in formation [ML^{-3}]
C_C = constant storage water casing concentration [ML^{-3}]

C_{BP} = concentration entering pump inlet at time increment i [ML^{-3}]
Q_{BP} = flow of water to the pump from beneath the inlet at time increment i [L^3T^{-1}]
Q_{AP} = flow of water to the pump from above the inlet at time increment i [L^3T^{-1}]
Q_T = Q_{AP} +Q_{BP} at time increment i [L^3T^{-1}].

At the start of purging, all water originates from storage in submersible pump casing. Thus, when

$$V_i < V_{PC}, \quad \left(\frac{C_P}{C_F}\right)_i = \left(\frac{C_C}{C_F}\right)_i$$

V_i = cumulative volume of water extracted water volume at time i [L^3]
V_{PC} = volume of water in submersible casing [L^3].

At the start of purging, the initial concentration of solute below the pump inlet and above the screened interval is equivalent to C_C but transitions to water from the screened interval over time. Thus, when

$$V_{i(BP)} < V_{SP}, \quad \left(\frac{C_{BP}}{C_F}\right)_i = \left(\frac{C_C}{C_F}\right)_i$$

and

$$V_{i(BP)} > V_{SP}, \quad \left(\frac{C_{BP}}{C_F}\right)_i = \left(\frac{C_S}{C_F}\right)_i$$

$$V_{i(BP)} = \Delta V_{i(BP)} + \Delta V_{i-1(BP)}.$$

V_{SP} = volume of water initially stored between the pump inlet and screened interval
$V_{i(BP)}$ = cumulative volume of water removed from below the pump inlet at time increment i
C_S = concentration exiting the screened interval at time increment i [ML^{-3}].

The cumulative volume of water extracted below the pump at time increment i is calculated by adding the cumulative volume of water extracted below the pump at time increment i-1 to the change in extracted volume below the pump which is calculated by

$$\Delta V_{i(BP)} = \Delta V_i \left(\frac{Q_{BP}}{Q_T}\right)_i$$

and

$$\Delta V_i = V_i - V_{i-1}.$$

The fraction of water originating below the pump to total water extracted is calculated by:

$$\left(\frac{Q_{BP}}{Q_T}\right)_i = 1 - \left(\frac{Q_{AP}}{Q_T}\right)_i$$

and

$$\left(\frac{Q_{AP}}{Q_T}\right)_i = \frac{\Delta D_i}{\Delta D_i^*}$$

$$\Delta D_i = D_i - D_{i-1}$$

$$\Delta D_i^* = \frac{\Delta V_i}{A_C}$$

$$A_C = \frac{\pi L_{CD}}{4B}\left(D_{ID-WC}^2 - D_{OD-PC}^2 - D_{OD-TL}^2\right)$$

D_i = total drawdown at time i [L]
ΔD_i^* = the change in drawdown at time i if all water during drawdown comes from above the pump.
A_C = volume per length of casing associated with drawdown [L^2] (7.12 liters/m drawdown at MW01)
L_{CD} = characteristic drawdown length [L] (1 m at MW01).

During recovery,

$$\Delta D_i < 0 \quad and \quad \left(\frac{Q_{AP}}{Q_T}\right)_i = 0$$

The concentration of solute in water exiting the screened interval then is calculated using a mass balance mixing equation:

$$V_S \frac{dC_S}{dt} = C_F Q_{BP} - C_S Q_{BP}$$

Since Q_{BP} is a function of time (calculated in increments using drawdown and flow data), C_S/C_F varies in increments of time

$$\left(\frac{C_S}{C_F}\right)_i = 1 - \left[1 - \left(\frac{C_S}{C_F}\right)_{i-1}\right]\exp\left(-\Delta\alpha_i\right)$$

where

$$\Delta\alpha_i = \alpha_i - \alpha_{i-1}$$

$$\alpha_i = \frac{V_{BP(i)}}{V_S}$$

α_i = cumulative screen volume exchanges at time increment i.
V_S = screen volume (casing + porosity of pre-packed screen + annular space between pre-packed screen and borehole wall).

At time 0, C_S equals initial concentration (C_0). V_S is a constant calculated by:

$$V_S = V_B - V_C + \frac{\pi}{4B} L_{SS} D_{ID-WC}^2 .$$

Input parameters to support modeling are summarized in Table SI E2.

Table SI E2. Well design and input parameters for calculation of casing, borehole, and screen exchange volumes during Phase V sampling event

Label	MW01		MW02	
	m	liters	m	liters
Depth below ground surface to static head	62.2		60.5	
Depth below ground surface to base of screen	239.3		298.7	
Length of submersible pump **(L_{SP})**	0.635		0.635	
Depth of base of submersible pump	232.7		297.2	
Depth of top of submersible pump casing	232.1		296.6	
Depth of schedule 80 PVC tag line	232.1		296.6	
Length of water column in well **(L_{WC})**	177.1		238.2	
Length of water in submerged pump casing **(L_{PC})**	232.1		296.6	
Length of submerged tag line **(L_{TL})**	169.9		236.0	
Length of stainless-steel pre-packed screen **(L_{SS})**	6.10		6.10	
Inside diameter of schedule 40 steel well casing **(ID_{WC})**	0.102		0.102	
Outside diameter of schedule-40 steel well casing **(OD_{WC})**	0.114		0.114	
Outside diameter of submersible pump casing **(OD_{PC})**	0.034		0.034	
Inside diameter of submersible pump casing **(ID_{PC})**	0.027		0.027	
Outside diameter of schedule 80 PVC tag line **(OD_{TL})**	0.033		0.033	
Inside diameter of schedule 80 PVC tag line **(ID_{TL})**	0.024		0.024	
Outside diameter of submersible pump **(OD_{SP})**	0.089		0.089	
Diameter of borehole **(D_{BH})**	0.251		0.251	
Outside diameter of pre-packed screen **(OD_{PP})**	0.216		0.216	
Effective porosity of pre-packed screen **(φ)** = 0.45				
Length from Bottom of Pump to top of Screen **(L_{PS})**	0.457		0.0	
Well casing volume **(V_C)**		1358		1792
Borehole volume **(V_B)**		1504		1942
Screen plus borehole volume **(V_S)**		200.6		196.8
Volume above screen and below pump **(V_{SP})**		3.76		0.0
Liters per meter of drawdown **(A_C)**		6.45		6.45
Volume of water in submersible pump casing **(V_{PC})**		129		165

E.4 Summary of Sample Results at MW01 and MW02

Table SI E3a. Summary of Organic Compound Detections in MW01

Target Organic Compounds	EPA Phase III	EPA Phase IV	USGS Phase V	EPA Phase V 0412-4	EPA Phase V 0412	EPA Phase V 0412-2	EPA Phase V 0412-3	EPA Phase V 0412-5	EPA Phase V 0412-7	EPA Phase V 0412-6	EPA Phase V 0412-8	EPA Phase V 0412-9	USGS Phase V	EPA Phase V 0412-10
Borehole Volumes	0.3	0.7	1.6 – 3.0	1.6	1.8	2.1	2.3	2.4	2.6	2.7	2.9	3.0	3.0	3.3
dissolved organic carbon (mg/L)	8.51^{O}	9.43^{O}	NA	NA	5.63^{O}/5.75^{O}	NA	NA	NA	NA	NA	NA	NA	NA	3.36^{O}
diesel range organics (µg/L)	634^{R8}	924^{R8}	180(J)^{T}/190(J)^{T}	555^{R8}	484^{R8}/476^{R8}	NA	NA	NA	379^{R8}	NA	NA	NA	85(J)^{T}/83(J)^{T}	267^{R8}
gasoline range organics (µg/L)	389^{R8}	592^{R8}	700(J+)^{T}/760(J+)^{T}	584^{R8}	528^{R8}/539^{R8}	531^{R8}	493^{R8}	461^{R8}	418^{R8}	444^{R8}	402^{R8}	410^{R8}	730(J+)^{T}/710(J+)^{T}	328^{R8}
benzene (µg/L)	<2.5^{R8}	<0.50^{S} <0.25(J-)^{R8}	<0.16^{T}/<0.16^{T}	<0.50^{S}	<0.50^{S} <0.25^{R8}/<0.25^{R8}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.16^{T}/<0.16^{T}	<0.50^{S} <0.25^{R8}
toluene (µg/L)	0.75^{R8}	0.59(B)^{S} <0.56(J-)^{R8}	<0.17^{T}/<0.17^{T}	<0.50^{S}	<0.50^{S}/<0.50^{S} <0.25^{R8}/<0.25^{R8}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.17^{T}/<0.17^{T}	<0.50^{S} <0.25^{R8}
m+p-xylene (µg/L)	<2.5^{R8}	0.49(J)^{S} 0.89(B,J-)^{R8}	<0.34^{T}/<0.34^{T}	<0.50^{S}	<0.50^{S}/<0.50^{S} <1.00^{R8}/<1.00^{R8}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.34^{T}/<0.34^{T}	<0.50^{S} <1.00^{R8}
o-xylene (µg/L)	<2.5^{R8}	0.38(J)^{S} <0.25(J-)^{R8}	<0.19^{T}/<0.19^{T}	<0.50^{S}	<0.50^{S}/0.06(J)^{S} <0.25^{R8}/<0.25^{R8}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.19^{T}/<0.19^{T}	<0.50^{S} <0.25^{R8}
ethylbenzene (µg/L)	<2.5^{R8}	0.21(J)^{S} <0.25(J-)^{R8}	<0.16^{T}/<0.16^{T}	<0.50^{S}	<0.50^{S}/<0.50^{S} <0.25^{R8}/<0.25^{R8}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.50^{S}	<0.16^{T}/<0.16^{T}	<0.50^{S} <0.25^{R8}
isopropylbenzene (µg/L)	<2.5^{R8}	<0.25(J-)^{R8}	<0.19^{T}/<0.19^{T}	NA	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	NA	NA	NA	NA	<0.19^{T}/<0.19^{T}	<0.25^{R8}
n-butylbenzene (µg/L)	<2.5^{R8}	<0.25(J-)^{R8}	<0.32^{T}/<0.32^{T}	NA	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	NA	NA	NA	NA	<0.32^{T}/<0.32^{T}	<0.25^{R8}
sec-butylbenzene (µg/L)	<2.5^{R8}	<0.25(J-)^{R8}	<0.17^{T}/<0.17^{T}	NA	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	NA	NA	NA	NA	<0.17^{T}/<0.17^{T}	<0.25^{R8}
tert-butylbenzene (µg/L)	<2.5^{R8}	<0.25(J-)^{R8}	<0.16^{T}/<0.16^{T}	NA	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	NA	NA	NA	NA	<0.16^{T}/<0.16^{T}	<0.25^{R8}
n-propylbenzene (µg/L)	<2.5^{R8}	<0.25(J-)^{R8}	<0.16^{T}/<0.16^{T}	NA	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	NA	NA	NA	NA	<0.16^{T}/<0.16^{T}	<0.25^{R8}
p-isopropyltoluene (µg/L)	<2.5^{R8}	<0.25(J-)^{R8}	<0.20^{T}/<0.20^{T}	NA	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	NA	NA	NA	NA	<0.20^{T}/<0.20^{T}	<0.25^{R8}
styrene (µg/L)	<2.5^{R8}	<0.25(J-)^{R8}	<0.17^{T}/<0.17^{T}	NA	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	NA	NA	NA	NA	<0.17^{T}/<0.17^{T}	<0.25^{R8}
1,3,5-trimethylbenzene (µg/L)	<2.5^{R8}	0.38(J)^{S} <0.25(J-)^{R8}	NA	<1.00^{S}	<1.00^{S}/0.15(J)^{S} <0.25^{R8}/<0.25^{R8}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	NA	<1.00^{S} <0.25^{R8}
1,2,4-trimethylbenzene (µg/L)	<2.5^{R8}	0.49(J)^{S} <0.25(J-)^{R8}	<0.15^{T}/<0.15^{T}	<1.00^{S}	<1.00^{S}/0.27(J)^{S} <0.25^{R8}/<0.25^{R8}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<0.15^{T}/<0.15^{T}	<1.00^{S} <0.25^{R8}
1,2,3-trimethylbenzene (µg/L)	NA	0.33(J)^{S}	<0.27^{T}/<0.27^{T}	<1.00^{S}	<1.00^{S}/0.26(J)^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<0.27^{T}/<0.27^{T}	<1.00^{S}
naphthalene (µg/L)	<2.5^{R8}	<1.0^{S} <0.25(J-)^{R8}	<0.22^{T}/<0.22^{T}	<1.00^{S} <1.00^{R8}	<1.00^{S}/3.78^{S} <0.25^{R8}/<0.25^{R8}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S} <1.00^{R8}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<0.22^{T}/<0.22^{T}	<1.00^{S} <0.25^{R8}
1-methylnapthalene (µg/L)	<0.10^{R8}	<0.50^{R8}	0.0096(J)^{T}/0.01(J)^{T}	<1.00^{R8}	<1.00^{R8}/<1.00^{R8}	NA	NA	NA	<1.00^{R8}	NA	NA	NA	<0.0057^{T}/<0.0058^{T}	<1.00^{R8}
2-methylnapthalene (µg/L)	<0.10^{R8}	<0.50^{R8}	0.0110(J)^{T}/0.011(J)^{T}	<1.00^{R8}	<1.00^{R8}/<1.00^{R8}	NA	NA	NA	<1.00^{R8}	NA	NA	NA	0.0072(J)^{T}/0.006(J)^{T}	<1.00^{R8}
phenol (µg/L)	10.7^{R8}	19.0^{R8}	10(J)^{T}/11^{T}	9.65^{R8}	8.09(J+)^{R8}/8.42^{R8}	NA	NA	NA	6.68^{R8}	NA	NA	NA	6.1(J)^{T}/6.6(J)^{T}	5.42^{R8}
2-methylphenol (µg/L)	<0.10^{R8}	<0.50^{R8}	<1^{T}/<1.1^{T}	<2.00^{R8}	<2.00^{R8}/<2.00^{R8}	NA	NA	NA	<2.00^{R8}	NA	NA	NA	<0.99^{T}/<1.0^{T}	<2.00^{R8}
3&4-methylphenol (µg/L)	0.34^{R8}	1.85^{R8}	0.95(J)^{T}/1.1(J)^{T}	<5.00^{R8}	<5.00^{R8}/<5.00^{R8}	NA	NA	NA	<5.00^{R8}	NA	NA	NA	0.47(J)^{T}/0.46(J)^{T}	<5.00^{R8}
2,4-dimethylphenol (µg/L)	<0.10^{R8}	<0.50^{R8}	<0.61(J-)^{T}/<0.62(J-)^{T}	<2.00^{R8}	<2.00^{R8}/<2.00^{R8}	NA	NA	NA	<2.00^{R8}	NA	NA	NA	<0.59(J-)^{T}/<0.59(J-)^{T}	<2.00^{R8}
isopropanol (µg/L)	NA	212^{S}	<13(J-)^{T}/<13(J-)^{T}	65.0(J)^{S}	69.8(J)^{S}/69.2(J)^{S}	74.8(J)^{S}	76.8(J)^{S}	82.2(J)^{S}	62.6(J)^{S}	77.4(J)^{S}	80.0(J)^{S}	68.5(J)^{S}	<13(J-)^{T}/<13(J-)^{T}	69.3(J)^{S}
n-propanol (µg/L)	NA	<100^{S}	NA	<100^{S}	1.7(J†)^{S}/<100^{S}	<100^{S}	<100^{S}	<100^{S}	<100^{S}	<100^{S}	<100^{S}	<100^{S}	NA	<100
methanol (µg/L)	NA	NA	NA	NA	<5000^{A}/<5000^{A} 863(J†)^{S}/831(J†)^{S}	NA	NA	NA	NA	NA	NA	NA	NA	<5000^{A}
ethanol (µg/L)	NA	NA	NA	NA	13.7 (J†)^{S}/ <100^{S}	<100^{S}	<100^{S}	<100^{S}	<100^{S}	<100^{S}	<100^{S}	<100^{S}	NA	<100^{S}
tert butyl alcohol (µg/L)	NA	<5.0^{S}	<11^{T}/<11^{T}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<11^{T}/<11^{T}	<5.0^{S}
acetone (µg/L)	NA	79.5(J-)^{R8}	<1.9^{T}/<1.9^{T}	<5.0^{S}	<5.0^{S} <5.0(C)^{R8}/<5.0(C)^{R8}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<5.0^{S}	<1.9^{T}/<1.9^{T}	<5.0^{S} <5(C)^{R8}
2-butanone (µg/L)	NA	<0.50(J-)^{R8}	<2^{T}/<2^{T}	NA	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	NA	NA	NA	NA	<2^{T}/<2^{T}	<0.25^{R8}
4-methyl-2-pentanone (µg/L)	NA	2.6(J-)^{R8}	<0.98^{T}/<0.98^{T}	NA	1.39(J)/1.37(J)	NA	NA	NA	NA	NA	NA	NA	<0.98^{T}/<0.98^{T}	0.59 (J)
benzoic acid (µg/L)	212^{R8}	457(J)^{R8}	340(J+)^{T}/360(J+)^{T}	735(J,D)^{R8}	221(D)^{R8}/309(D)^{R8}	NA	NA	NA	310(D)^{R8}	NA	NA	NA	190(J+)^{T}/200(J+)^{T}	237(D)^{R8}
ethylene glycol (µg/L)	NA	NA	<8630^{T}/<8630^{T}	NA	<5000^{A}/<5000^{A}	NA	NA	NA	NA	NA	NA	NA	<8630^{T}/<8630^{T}	<5000^{A}
propylene glycol (µg/L)	NA	NA	<18700^{T}/<18700^{T}	NA	<5000^{A}/<5000^{A}	NA	NA	NA	NA	NA	NA	NA	<18700^{T}/<18700^{T}	<5000^{A}
diethylene glycol (µg/L)	NA	226(J+)^{R3}	<7730^{T}/<7730^{T}	60.0(J)^{R3}	53.9(J)^{R3}/53.9(J)^{R3}	NA	NA	NA	34.1(J)^{R3}	NA	NA	NA	<7730^{T}/<7730^{T}	26.4(J)^{R3}
triethylene glycol (µg/L)	NA	46(J-)^{R3}	<8450^{T}/<8450^{T}	12.7(J-)^{R3}	11.5(J-)^{R3}/11.6(J-)^{R3}	NA	NA	NA	4.9(J-)^{R3}	NA	NA	NA	<8450^{T}/<8450^{T}	2.9 (J-)^{R3}
tetraethylene glycol (µg/L)	NA	7.3 (J-,B)^{R3}	NA	<10.0(J-)^{R3}	<10.0(J-)^{R3}/<10.0(J-)^{R3}	NA	NA	NA	<10.0 (J)^{R3}	NA	NA	NA	NA	<10.0 (J-)^{R3}
2-butoxyethanol (µg/L)	<0.25^{R8}	<10(J-)^{R3} 12.7^{R8}	NA	5.1(J-)^{R3} <1.00^{R8}	3.5(J-)^{R3}/3.0(J-)^{R3} <1.00^{R8}/5.78^{R8}	NA	NA	NA	1.5 (J-)^{R3} 3.49^{R8}	NA	NA	NA	NA	<5.0(J-)^{R3} <1.00^{R8}
ethyl ether (µg/L)	<0.25^{R8}	<0.25(J-)^{R8}	<0.26^{T}/<0.26^{T}	NA	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	NA	NA	NA	NA	<0.26^{T}/<0.26^{T}	<0.25^{R8}
nonylphenol (µg/l)	NA	NA	NA	0.65(J-,B)^{L}	0.60(J-,B)^{L}/0.57(J-,B)^{L}	NA	NA	NA	0.65(J,B)^{L}	NA	NA	NA	NA	0.24(J-,B)^{L}
octylphenol (µg/L)	NA	NA	NA	0.16(J)^{L}	0.14(J)^{L}/0.13(J)^{L}	NA	NA	NA	0.10 (J)^{L}	NA	NA	NA	NA	0.051(J)^{L}
acrylamide (µg/L)	NA	NA	NA	<0.20^{L}	<0.20^{L}/<0.20^{L}	NA	NA	NA	<0.20^{L}	NA	NA	NA	NA	<0.20^{L}
lactate (µg/L)	NA	69(J)^{S}	NA	NA	<100(R)^{S}/<100(R)^{S}	NA	NA	NA	NA	NA	NA	NA	NA	<100(R)^{S}
formate (µg/L)	NA	112^{S}	NA	NA	<100(R)^{S}/<100(R)^{S}	NA	NA	NA	NA	NA	NA	NA	NA	<100(R)^{S}
acetate (µg/L)	NA	8050^{S}	NA	NA	3420(D)^{S}/5960(D)^{S}	NA	NA	NA	NA	NA	NA	NA	NA	6080^{S}
propionate (µg/L)	NA	309^{S}	NA	NA	75(J)^{S}/95(J)^{S}	NA	NA	NA	NA	NA	NA	NA	NA	0.084(J)^{S}
adamantine (µg/L)	<2.5^{R8}	<0.25(J-)^{R8}	NA	<1.00^{R8}	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	<1.00^{R8}	NA	NA	NA	NA	<0.25^{R8}
1,3-dimethyl adamantine (µg/L)	<2.5^{R8}	<0.25(J-)^{R8}	NA	<1.00^{R8}	<0.25^{R8}/<0.25^{R8}	NA	NA	NA	<1.00^{R8}	NA	NA	NA	NA	<0.25^{R8}
methylene blue active substances (mg/l)	NA	NA	NA	<0.2^{T}	<0.2^{T}/<0.2^{T}	NA	NA	NA	<0.2^{T}	NA	NA	NA		<0.2^{T}

Table SI E3b. Summary of Field Parameters, Major Ions, and Dissolved Metals at MW01

Inorganics	EPA Phase III	EPA Phase IV	USGS Phase V	EPA Phase V 0412-4	EPA Phase V 0412	EPA Phase V 0412-2	EPA Phase V 0412-3	EPA Phase V 0412-5	EPA Phase V 0412-7	EPA Phase V 0412-6	EPA Phase V 0412-8	EPA Phase V 0412-9	USGS Phase V	EPA Phase V 0412-10
Borehole Volumes	0.3	0.7	1.6-3.0	1.6	1.8	2.1	2.3	2.4	2.6	2.7	2.9	3.0	3.0	3.3
Field Parameters														
pH	11.91	11.79	11.4	11.43	11.34/11.34	11.20	11.16	11.08	11.01	10.94	10.89	10.80	10.7	10.71
specific conductance (µS/cm)	3265	2352	1621	1539	1489/1489	1413	1393	1371	1354	1336	1335	1318	1373	1307
dissolved oxygen (mg/l)	0.17	0.03	<0.20	0.01	0.00/0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	<0.20	0.01
oxidation reduction potential (mV)	114	-116	-343.7	-395	-388/-388	-393	-394	-391	-397	-395	-385	-383	-389.8	-379
turbidity (NTU)	7.5	7.9	NM	NA	2.0	NA	NA	NA	NA	NA	NA	NA	NM	2.6
alkalinity (mg/l CaCO3)	430	388	215	NA	213/213	NA	NA	NA	NA	NA	NA	NA	174/182	181
Major Ions														
nitrate + nitrite (mg N/l)	0.150(B)^{O}	<0.100^{O}	<0.019^{T}/<0.019^{T}	NA	0.120^{O}/<0.050^{O}	NA	NA	NA	NA	NA	NA	NA	<0.02^{T}	<0.050^{O}
ammonia (mg N/l)	4.61^{O}	4.25^{O}	0.79(B)^{T}/0.79(B)^{T}	NA	1.81^{O}/1.60^{O}	NA	NA	NA	NA	NA	NA	NA	0.34(B)^{T}	0.490^{O}
SO4 (mg/L)	398^{O}	339^{O}	380^{T}/380^{T}	391^{O}	390^{O}/388^{O}	397^{O}	394^{O}	406^{O}	407^{O}	401^{O}	411^{O}	413^{O}	410^{T}	428^{O}
S (mg/L)	158(J)	141(J)	NA	187(J)^{S}	177(J)^{S}/171(J)^{S}	202(J)^{S}	198(J)^{S}	210(J)^{S}	210(J)^{S}	208(J)^{S}	210(J)^{S}	214(J)^{S}	NA	200(J)^{S}
Cl (mg/l)	23.3^{O}	23.1^{O}	26^{T}/26^{T}	21.0^{O}	19.4^{O}/20.9^{O}	22.0^{O}	21.0^{O}	21.2^{O}	21.0^{O}	21.5^{O}	21.6^{O}	20.8^{O}	27^{T}	21.2^{O}
Br (mg/l)	NA	<3.00^{O}	0.2(J)^{T}/0.2(J)^{T}	<1.00^{O}	<1.00^{O}/<1.00^{O}	<1.00^{O}	<1.00^{O}	<1.00^{O}	<1.00^{O}	<1.00^{O}	<1.00^{O}	<1.00^{O}	0.2(J)^{T}	<1.00^{O}
F (mg/l)	1.55^{O}	1.88^{O}	3^{T}/3^{T}	2.24^{O}	2.29^{O}/2.33^{O}	2.37^{O}	2.11^{O}	2.29^{O}	2.01^{O}	2.33^{O}	2.13^{O}	2.06^{O}	3^{T}	2.01^{O}
K (mg/l)	54.9^{S}	24.7^{S}	15.0^{T}/16.0^{T}	17.8^{S}	17.3^{S}/17.2^{S}	16.2^{S}	16.0^{S}	15.7^{S}	15.3^{S}	15.0^{S}	14.5^{S}	14.4^{S}	13.0^{T}	13.6^{S}
Na (mg/l)	334^{S}	304^{S}	270^{T}/280^{T}	273^{S}	276^{S}/277^{S}	271^{S}	264^{S}	265^{S}	265^{S}	264^{S}	264^{S}	268^{S}	280^{T}	264^{S}
Ca (mg/l)	15.6^{S}	13.6^{S}	9.4^{T}/9.4^{T}	9.80^{S}	9.87/9.91^{S}	9.75^{S}	9.67^{S}	9.69^{S}	9.67^{S}	9.66^{S}	9.61^{S}	9.65^{S}	8.90^{T}	9.47^{S}
Mg (mg/l)	0.05(B)^{S}	0.12^{S}	0.14(J)^{T}/0.15(J)^{T}	0.13^{S}	0.14^{S}/0.15^{S}	0.14^{S}	0.15^{S}	0.15^{S}	0.16^{S}	0.16^{S}	0.16^{S}	0.17^{S}	0.17(J)^{T}	0.17^{S}
Si (mg/L)	8.02(J)^{S}	10.2(J)^{S}	9.0^{T}/8.7^{T}	12.00(J+)^{S}	10.50(J+)^{S}/10.50(J+)^{S}	10.10(J+)^{S}	9.95(J+)^{S}	9.54(J+)^{S}	9.09(J+)^{S}	8.81(J+)^{S}	8.43(J+)^{S}	8.18(J+)^{S}	6.4^{T}	7.69(J+)^{S}
Dissolved Metals														
Ag (µg/L)	<51^{S}	<51^{S}	<0.033^{T}/<0.033^{T}	<14^{S}	<14^{S}/<14^{S}	<14^{S}	<14^{S}	<14^{S}	<14^{S}	<14^{S}	<14^{S}	<14^{S}	<0.033^{T}	<14^{S}
Al (µg/L)	422(J)^{S}	382(J)^{S}	170^{T}/170^{T}	205(J)^{S}	234(J)^{S}/245(J)^{S}	211(J)^{S}	<494^{S}	<494^{S}	<494^{S}	<494^{S}	<494^{S}	<494^{S}	100^{T}	<494^{S}
As (µg/L)	<51^{S}	<51^{S}	0.62(J)^{T}/<0.33^{T}	0.40(J)^{C}	0.49(J)^{C}/0.71(J)^{C}	<1.00^{C}	0.53(J)^{C}	0.28(J)^{C}	0.82(J)^{C}	0.47(J)^{C}	0.43(J)^{C}	0.59(J)^{C}	<0.33^{T}	<1.00^{C}
B (µg/L)	154(J)^{S}	117(J)^{S}	130^{T}/130^{T}	142(J)^{S}	136(J)^{S}/136(J)^{S}	131(J)^{S}	130(J)^{S}	128(J)^{S}	126(J)^{S}	125(J)^{S}	123(J)^{S}	121(J)^{S}	120^{T}	119(J)^{S}
Ba (µg/L)	41(J)^{S}	26(J)	23^{T}/20^{T}	21(J)^{S}	21(J)^{S}/21(J)^{S}	20(J)^{S}	20(J)^{S}	20(J)^{S}	20(J)^{S}	20(J)^{S}	20(J)^{S}	20(J)^{S}	21^{T}	19(J)^{S}
Be (µg/L)	<4^{S}	<4^{S}	<0.08^{T}/<0.08^{T}	<10^{S}	<10^{S}/<10^{S}	<10^{S}	<10^{S}	<10^{S}	<10^{S}	<10^{S}	<10^{S}	<10^{S}	<0.08^{T}	<10^{S}
Cd (µg/L)	<4	<4^{S}	<0.1^{T}/<0.1^{T}	<1.00^{S}	<1.00^{S}/<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<0.1^{T}	<1.00^{S}
Co (µg/L)	<4^{S}	<4^{S}	<0.054^{T}/<0.054^{T}	<4^{S}	<4^{S}/<4^{S}	<4^{S}	<4^{S}	<4^{S}	<4^{S}	<4^{S}	<4^{S}	<4^{S}	<0.004^{T}	<4^{S}
Cr (µg/L)	<4^{S}	<4^{S}	<0.5^{T}/<0.5^{T}	<2.00^{S}	2.2^{S}/<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<0.5^{T}	<2.00^{S}
Cu (µg/L)	<9^{S}	<9^{S}	<0.56^{T}/<0.56^{T}	<2.00^{S}	<2.00^{S}/<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<0.56^{T}	<2.00^{S}
Fe (µg/L)	<63^{S}	>63^{S}	<22^{T}/<22^{T}	<67^{S}	<67^{S}/<67^{S}	<67^{S}	<67^{S}	<67^{S}	<67^{S}	<67^{S}	<67^{S}	<67^{S}	<22^{T}	<67^{S}
Hg (µg/L)	NA	NA	<0.027^{T}/<0.027^{T}	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.027^{T}	NA
Li (µg/L)	NA	NA	44^{T}/45^{T}	NA	NA	NA	NA	NA	NA	NA	NA	NA	33^{T}	NA
Mn (µg/L)	<4^{S}	<4^{S}	<0.31^{T}/1^{T}	<14^{S}	<14^{S}/<14^{S}	<14^{S}	<14^{S}	<14^{S}	<14^{S}	<14^{S}	<14^{S}	<14^{S}	0.42(J)^{T}	<14^{S}
Mo (µg/L)	20^{S}	<7^{S}	10^{T}/9.7^{T}	7(J)^{S}	7(J)^{S}/8(8)^{S}	5(J)^{S}	<17^{S}	<17^{S}	<17^{S}	<17^{S}	<17^{S}	<17^{S}	7.6^{T}	<17^{S}
Ni (µg/L)	1(J)^{S}	3(J)^{S}	<0.3^{T}/<0.3^{T}	<1.00^{S}	<1.00^{S}/0.39(J)^{S}	<1.00^{S}	0.23(J)^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<0.3^{T}	<1.00^{S}
P (µg/L)	<0.014^{S}	<0.014^{S}	57^{T}/89^{T}	<0.06^{S}	<0.06^{S}/<0.06^{S}	<0.06^{S}	<0.06^{S}	<0.06^{S}	<0.06^{S}	<0.06^{S}	<0.06^{S}	<0.06^{S}	61^{T}	<0.06^{S}
Pb (µg/L)	<11^{S}	<11^{S}	<0.18^{T}/<0.18^{T}	<1.00^{S}	<1.00^{S}/<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<0.18^{T}	<1.00^{S}
Sb (µg/L)	R^{S}	R^{S}	<0.4^{T}/0.54(B)^{T}	<2.00^{S}	<2.00^{S}/<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<2.00^{S}	<0.4^{T}	<2.00^{S}
Se (µg/L)	<16^{S}	<16^{S}	<0.7/<0.7	<5.00^{S}	<5.00^{S}/<5.00^{S}	<5.00^{S}	<5.00^{S}	<5.00^{S}	<5.00^{S}	<5.00^{S}	<5.00^{S}	<5.00^{S}	<0.7^{T}	<5.00^{S}
Sr (µg/L)	801^{S}	441^{S}	300^{T}/310^{T}	328^{S}	315^{S}/314^{S}	312^{S}	309^{S}	307^{S}	304^{S}	301^{S}	298^{S}	301^{S}	280^{T}	291^{S}
Ti (µg/L)	<4^{S}	<4^{S}	<0.6^{T}/<0.6^{T}	<7^{S}	<7^{S}/<7^{S}	<7^{S}	<7^{S}	<7^{S}	<7^{S}	<7^{S}	<7^{S}	<7^{S}	<0.6^{T}	<7^{S}
Tl (µg/L)	<37^{S}	R^{S}	<0.05^{T}/<0.05^{T}	<1.00^{S}	<1.00^{S}/<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<1.00^{S}	<0.05^{T}	<1.00^{S}
U (µg/L)	NA	NA	<0.05^{T}/<0.05^{T}	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.05^{T}	NA
V (µg/L)	4(J)^{S}	NA	0.6(J)^{T}/<0.5^{T}	<10^{S}	<10^{S}/<10^{S}	<10^{S}	<10^{S}	<10^{S}	<10^{S}	<10^{S}	<10^{S}	<10^{S}	<0.5^{T}	<10^{S}
Zn (µg/L)	<24^{S}	<24^{S}	<2^{T}/<2^{T}	<50^{S}	<50^{S}/<50^{S}	<50^{S}	<50^{S}	<50^{S}	<50^{S}	<50^{S}	<50^{S}	<50^{S}	<2^{T}	<50^{S}

Laboratories (Superscript)

S	Shaw Environmental, Ada, OK (Contractor to EPA)	O	EPA ORD Ada, OK	L	EPA ORD, Las Vegas, NV
R8	EPA Region 8 Laboratory, Golden, CO	R3	EPA Region 3 Laboratory, Fort Meade, MD	T	Test America Laboratory (Contractor to USGS and EPA)
U	U.S. Geological Survey National Water Quality Laboratory	A	ALS Environmental (Contractor to EPA)		
C	Chemtech Consulting (contractor to EPA)	E	Eberline Laboratory (contractor to USGS)		

Data Qualifiers

NA	Not analyzed
J	Estimated (non-attainment of quality control criteria or below reporting limit. R3 and ORD Las Vegas analysis are estimated because of method development)
J-	Estimated (biased low due <70% matrix spike recovery in USGS samples, exceedance of holding time in R8 Phase IV samples, or other quality assurance factors)
J+	Estimated (biased high due to >130% matrix spike recovery in USGS samples or other quality assurance factors)
†	Estimated (method development on alcohols)[65,66]
B	Analyte in sample < 10X and < 5X concentration detected in a blank for EPA and USGS data respectively
D	Relative percent difference outside acceptance criteria
R	Sample result rejected due to serious deficiencies in analysis
C	Acetone result in Phase V corrected from EPA (2012)

Table SI E4a. Summary of Organic Compound Detections in MW02

Compound	EPA Phase III	EPA Phase IV	EPA Phase V 0412-1	EPA Phase V 0412-2	USGS Phase V 0412-2
Borehole Volumes	0.1	0.6	0.0	1.0	1.0
dissolved organic carbon (mg/L)	14.5^{O}	19.7^{O}	19.4^{O}	15.5^{O}	13^{T}
diesel range organics (µg/l)	1440(J)^{R8}	4050(D)^{R8}/4200(D)^{R8}	4150^{R8}	2100^{R8}	670^{T}
gasoline range organics (µg/l)	3710^{R8}	2800^{R8}/3200^{R8}	4500^{R8}	5290^{R8}	6800^{T}/7700^{T}
benzene (µg/l)	246^{R8}	183^{S}/191^{S} 139(J-)^{R8}/164(J-)^{R8}	166^{S} 175(J)^{R8}	232^{S} 247(J)^{R8}	250^{T}/260^{T}
toluene (µg/l)	617^{R8}	482^{S}/464^{S} 336(J-)^{R8}/424(J-)^{R8}	402^{S} 437(J)^{R8}	607^{S} 677(J)^{R8}	690^{T}/710^{T}
ethylbenzene (µg/l)	67.0^{R8}	68.7^{S}/62.0^{S} 21.5(J-)^{R8}/27.0(J-)^{R8}	61.1^{S} 57.0(J)^{R8}	101^{S} 89.6(J)^{R8}	100^{T}/100^{T}
m,p - xylenes (µg/l)	572^{R8}	630^{S}/554^{S} 280(J-)^{R8}/354(J-)^{R8}	549^{S} 578(J)^{R8}	894^{S} 973(J)^{R8}	1000^{T}/1000^{T}
o-xylene (µg/l)	178^{R8}	175^{S}/160^{S} 81.6(J-)^{R8}/102(J-)^{R8}	161^{S} 164(J)^{R8}	245^{S} 253(J)^{R8}	260^{T}/250^{T}
isopropylbenzene (µg/l)	11.0^{R8}	<12.5(J-)^{R8}/<12.5(J-)^{R8}	9.03(J)^{R8}	9.40(J)^{R8}	11(J)^{T}/12(J)^{T}
n-butylbenzene (µg/l)	<6.25^{R8}	<12.5(J-)^{R8}/<12.5(J-)^{R8}	0.38(J)^{R8}	<5.0^{R8}	<6.4^{T}/<6.4^{T}
sec-butylbenzene (µg/l)	<6.25^{R8}	<12.5(J-)^{R8}/<12.5(J-)^{R8}	1.05(J)^{R8}	<5.0^{R8}	<3.4^{T}/<3.4^{T}
tert-butylbenzene (µg/l)	<6.25^{R8}	<12.5(J-)^{R8}/<12.5(J-)^{R8}	0.83(J)^{R8}	<5.0^{R8}	<3.2^{T}/<3.2^{T}
n-propylbenzene (µg/l)	5.75(J)^{R8}	<12.5(J-)^{R8}/<12.5(J-)^{R8}	9.94(J)^{R8}	11.8(J)^{R8}	13(J)^{T}/12(J)^{T}
p-isopropyltoluene (µg/l)	<6.25^{R8}	<12.5(J-)^{R8}/<12.5(J-)^{R8}	1.36(J)^{R8}	<5.0^{R8}	<4.0^{T}/<4.0^{T}
styrene (µg/l)	<6.25^{R8}	<12.5(J-)^{R8}/<12.5(J-)^{R8}	0.43(J)^{R8}	<5.0^{R8}	<3.4^{T}/<3.4^{T}
1,3,5-trimethylbenzene (µg/l)	35.5^{R8}	43.6^{S}/35.0^{S}	39.5^{S}	71.4^{S}	86^{T}/91^{T}
1,2,4-trimethylbenzene (µg/l)	69.2^{R8}	84.1^{S}/67.2^{S} 18.5(J-)^{R8}/23.0(J-)^{R8}	77.0^{S}	148^{S}	140^{T}/150^{T}
1,2,3-trimethylbenzene (µg/l)	NA	28.8^{S}/23.8^{S}	27.6^{S}	45.5^{S}	45^{T}/46^{T}
naphthalene (µg/l)	1.41^{R8}/4.25(J)^{R8}	4.61^{S}/3.87^{S} 3.32^{R8}/<5.0^{R8} <12.5(J-)^{R8}/<12.5(J-)^{R8}	4.89^{S} 7.19(J)^{R8}/4.29^{R8}	7.49^{S} 7.20(J)^{R8}/4.78^{R8}	7.2(J)^{T}/7.9(J)^{T}
1-methylnapthalene (µg/l)	0.66^{R8}	1.03^{R8}/<5.00^{R8}	2.23^{R8}	2.85^{R8}	3.5^{T}
2-methylnapthalene (µg/l)	1.15^{R8}	1.75^{R8}/<5.0^{R8}	4.08^{R8}	5.52^{R8}	6.7^{T}
phenol (µg/l)	13.7^{R8}	14.5^{R8}/29.2^{R8}	32.7(J-)^{R8}	16.0^{R8}	23^{T}
2-methylphenol (µg/l)	13.8^{R8}	10.3^{R8}/20.9^{R8}	22.2^{R8}	20.8(J)^{R8}	25^{T}
3&4-methylphenol (µg/l)	26.2^{R8}	16.9(D)^{R8}/34.6(D)^{R8}	39.8^{R8}	33.5^{R8}	45^{T}
2,4-dimethylphenol (µg/l)	28.6^{R8}	23.2(D)^{R8}/46.3(D)^{R8}	36.6(J+)^{R8}	32.0^{R8}	67^{T}
isopropanol (µg/l)	NA	581^{S}/583^{S}	862^{S}	802^{S}	<260^{T}
n-propanol (µg/l)	NA	<100^{S}/<100^{S}	63(J-)^{S}	11.8(J†)^{S}/<100(J-)^{S}	NA
methanol (µg/l)	NA	NA	<5000^{A}	<5000^{A} 592(J†)^{S}	NA
tert-butyl alcohol (µg/l)	NM	4470^{S}/4580^{S}	5910^{S}	5395(†)^{S}/6120^{S}	6300^{T}/6300^{T}
acetone (µg/l)	NA	641(J-)^{R8}/616(J-)^{R8}	1460^{S} 982(J)^{R8}	231^{S} 157(J)^{R8}	350^{T}/450^{T}
2-butanone (MEK) (µg/l)	NA	120(J-)^{R8}/118(J-)^{R8}	208(J)^{R8}	86.2(J)^{R8}	<120^{T}/<40^{T}
4-methyl-2-pentanone (MIBK) (µg/l)	NA	12.5(J-)^{R8}/<12.5(J-)^{R8}	<0.25^{R8}	<5.0^{R8}	<20^{T}
benzoic acid (µg/l)	244^{R8}	209(D)^{R8}/364(D)^{R8}	513^{R8}	110(D)^{R8}	190^{T}
ethylene glycol (µg/l)	NA	NA	<5000^{A}	<5000^{A}	<8630^{T}
propylene glycol (µg/l)	NA	NA	<5000^{A}	<5000^{A}	<18700^{T}
diethylene glycol (R3) (µg/l)	NA	1570(J+)^{R3}/1610(J+)^{R3}	1260(J-)^{R3}	378(J)^{R3}	<7730^{T}
triethylene glycol (R3) (µg/l)	NA	310(J-)^{R3}/293(J-)^{R3}	262(J-)^{R3}	72.3(J)^{R3}	<8450^{T}
tetraethylene glycol (R3) (µg/l)	NA	27.2(J,B)^{R3}/29.0(J-,B)^{R3}	22.6(J-)^{R3}	3.6(J)^{R3}	NA
2-butoxyethanol (µg/l)	NA	<0.10(J-)^{R3}/<0.10(J-)^{R3} <0.10(J-)^{R8}/<0.10(J-)^{R8}	6.8(J-)^{R3} <1.0^{R8}	<5.0^{R3} <1.0^{R8}	TIC^{T}
ethyl ether (µg/l)	<6.25^{R8}	12.5(J-)^{R8}/<12.5(J-)^{R8}	1.94(J)^{R8}	<5.0^{R8}	<5.2^{T}
nonylphenol (µg/l)	NA	NA	28(J-)^{L}	7.4-7.9(J-)^{L}	NA
octylphenol (µg/l)	NA	NA	2.9 (J-)^{L}	0.5-0.7(J)^{L}	NA
acrylamide (µg/L)	NA	NA	<0.20^{L}	<0.20^{L}	NA
lactate (µg/L)	NA	213^{S}/253^{S}	250^{S}	<100^{S}	NA
formate (µg/L)	NA	558^{S}/584^{S}	R	R	NA
acetate (µg/L)	NA	4310^{S}/4200^{S}	4800^{S}	2840(J)^{S}	NA
propionate (µg/L)	NA	808^{S}/687^{S}	844^{S}	687(J)^{S}	NA
adamantine (µg/L)	<6.25^{R8}	<12.5(J-)^{R8}/<12.5(J-)^{R8}	<0.25^{R8}	<5.0^{R8}	NA
1,3-dimethyl adamantine (µg/L)	>0.20^{R8}/<6.25^{R8}	<0.10(J-)^{R8}/<5.0(J-)^{R8}	<0.25^{R8}	<5.0^{R8}	NA
methylene blue active substances (mg/l)	NA	NA	<0.20^{T}	<0.20^{T}	0.12(J)^{T}

Table SI E4b. Summary of Field Parameters, Major Ions, and Dissolved Metals at MW02

Compound	EPA Phase III	EPA Phase IV	EPA Phase V 0412-1	EPA Phase V 0412-2	USGS Phase V 0412-2
Borehole Volumes	0.1	0.6	0.0	1.0	1.0
Field Parameters					
pH	12.01	11.78	11.96	11.81	NM
specific conductance (µS/cm)	3812	3099	3313	2888(J)	NM
dissolved oxygen (mg/l)	0.0	0.02	0.02	0.01	NM
oxidation reduction potential (mV)	121	-108	-154	-148	NM
turbidity (NTU)	28.8	24.0	4.5	15.7	NM
alkalinity (mg/l CaCO3)	456	482	390	254	NM
Major Ions					
nitrate + nitrite (mg N/L) (mg/L)	0.379(B)^{O}	<0.100^{O}/<0.100^{O}	0.056^{O}	0.095^{O}	<0.019
ammonia (mg N/L)	1.95^{O}	2.88^{O}/2.82^{O}	2.61^{O}	1.23^{O}	0.81(B)
SO4 (mg/l)	12.1^{O}	62.6^{O}/62.5^{O}	81.8^{O}	13.5^{O}	14
S (mg/L)	6.8(B)	25.1(J)^{S}/25.0(J)^{S}	32.1(J)^{S}	7.38(J)^{S}	NA
Cl (mg/l)	466^{O}	457^{O}/456^{O}	469^{O}	495^{O}	520
Br (mg/l)	NA	<3.00^{O}/<3.00^{O}	<1.00^{O}	<1.00^{O}	1.9
F (mg/l)	1.01^{O}	1.54(J)^{O}/1.49(J)^{O}	1.50^{O}	1.16^{O}	1.6
K (mg/l)	39.5(J)^{S}	43.6(J)^{S}/44.0(J)^{S}	31.4(J)^{S}	16.6(J)^{S}	15.0
Na (mg/l)	420(J)^{S}	448(J)^{S}/449(J)^{S}	429(J)^{S}	379(J)^{S}	400(B)
Ca (mg/l)	73.3^{S}	60.5^{S}/60.6^{S}	50.8^{S}	36.1^{S}	33.0
Mg (mg/l)	<0.05^{S}	0.03(J)^{S}/0.02(J)^{S}	<0.10^{S}	<0.10^{S}	49(J)
Si (mg/L)	3.00(J)^{S}	2.94(J)^{S}/2.93(J)^{S}	4.89(J+)^{S}	5.00(J+)^{S}	15.0
Dissolved Metals					
Ag (µg/L)	<51^{S}	<51^{S}	<14^{S}	<14^{S}	<0.033
Al (µg/L)	577(J)^{S}	684(J)^{S}/736(J)^{S}	660(J)^{S}	816(J)^{S}	700
As (µg/L)	<51^{S}	<51^{S}/<51^{S}	3.1^{S}	3.4^{S}	3.1(J)
B (µg/L)	103(J)^{S}	109(J)^{S}/108(J)^{S}	114(J)^{S}	108(J)^{S}	110
Ba (µg/L)	210(J)^{S}	93(J)^{S}/93(J)^{S}	95(J)^{S}	147(J)^{S}	150
Be (µg/L)	<4^{S}	<4^{S}/<4^{S}	<10^{S}	<10^{S}	<0.08
Cd (µg/L)	<4^{S}	<4^{S}/<4^{S}	<1.00^{S}	<1.00^{S}	<0.1
Co (µg/L)	<4^{S}	<4^{S}/<4	<4^{S}	<4^{S}	0.085
Cr (µg/L)	<4^{S}	<4^{S}/<4^{S}	<2.00^{S}	<2.00^{S}	4.5
Cu (µg/L)	<9^{S}	<9^{S}/<9^{S}	<2.00^{S}	4.4^{S}	3.7
Fe (µg/L)	<63^{S}	19(J)^{S}/<63^{S}	<67^{S}	151^{S}	400
Hg (µg/L)	NA	NA	NA	NA	<0.027
Li (µg/L)	NA	NA	NA	NA	25
Mn (µg/L)	<4^{S}	<4^{S}/<4^{S}	<14^{S}	<14^{S}	5.6
Mo (µg/L)	14^{S}	13^{S}/14^{S}	6(J)^{S}	<14^{S}	2.1
Ni (µg/L)	4^{S}	2^{S}/2(J)^{S}	4.3^{S}	2.6^{S}	6
P (µg/L)	<0.014^{S}	0.014(B)^{S}/0.024(B)^{S}	<0.06^{S}	<0.06^{S}	65
Pb (µg/L)	<11^{S}	<11^{S}/<11^{S}	<1.00^{S}	<1.00^{S}	<0.018
Sb (µg/L)	R^{S}	R^{S}/R^{S}	<2.00^{S}	<2.00^{S}	1.3(B)
Se (µg/L)	14(J)^{S}	<16^{S}/9(J)^{S}	4.7(J)^{S}	4.9(J)^{S}	<0.7
Sr (µg/L)	2020^{S}	1780^{S}/1790^{S}	1260^{S}	806^{S}	780
Ti (µg/L)	<4^{S}	<4^{S}/<4^{S}	<7^{S}	<7^{S}	2.7(J)
Tl (µg/L)	<37^{S}	R^{S}/R^{S}	<1.00^{S}	<1.00^{S}	<0.05
U (µg/L)	NA	NA	NA	NA	<0.05
V (µg/L)	<7^{S}	<7^{S}/<7^{S}	<10^{S}	<10^{S}	2.1(J)
Zn (µg/L)	<24^{S}	32^{S}/24^{S}	<50^{S}	<50^{S}	49

Laboratories (Superscript)

S	Shaw Environmental, Ada, OK (Contractor to EPA)	O	EPA ORD Ada, OK
L	EPA ORD, Las Vegas, NV	R8	EPA Region 8 Laboratory, Golden, CO
R3	EPA Region 3 Laboratory, Fort Meade, MD	T	Test America Laboratory (Contractor to USGS and EPA)
U	USGS Laboratory	A	ALS Environmental (Contractor to EPA)
C	Chemtech Consulting (contractor to EPA)		

Data Qualifiers

NA	Not analyzed
J	Estimated because of non-attainment of certain quality control criteria or concentration below quantitation limit. R3 and ORD Las Vegas analysis are estimated because of method development.
J-	Result is estimated because but may be biased low due <70% matrix spike recovery in USGS samples, exceedance of holding time in R8 Phase IV samples, or other quality assurance factors.
J+	Result is estimated but may be biased high due to >130% matrix spike recovery in USGS samples or other quality assurance factors.
J(†)	Estimated because of method development on alcohols (Shaw 2012,,b)
B	Analyte in sample < 10X and < 5X concentration detected in a blank for EPA and USGS data respectively
D	Relative percent difference outside acceptance criteria
R	Sample result rejected due to serious deficiencies in analysis

Table SI E5. Light Hydrocarbon and Isotope Analysis of Production Wells and EPA Monitoring Wells

	BH vol	C_1 (mg/L)	C_2 (mg/L)	C_3 (mg/L)	C_4 (mg/L)	$^{14}C_1$ (% pmc)	$\delta^{13}C_1$ (‰)	δDC_1 (‰)	$\delta^{13}C_2$ (‰)	δDC_2 (‰)	$\delta^{13}C_3$ (‰)	δDC_3 (‰)	$\delta^{13}iC_4$ (‰)	$\delta^{13}nC_4$ (‰)
Johnson and Rice (1993)														
Tribal Pavillion 14-6 (WR) (g)	-----	-----	------	-----	-----	NA	-39.24	NA	NA	NA	NA	NA	NA	NA
Govt 21-5 (WR) (g)	-----	-----	------	-----	-----	NA	-40.2	NA	NA	NA	NA	NA	NA	NA
Tribal Pavillion 41-9 (FU) (g)	-----	-----	------	-----	-----	NA	-38.04	NA	NA	NA	NA	NA	NA	NA
Tribal Pavillion 14-11 (FU) (g)	-----	-----	------	-----	-----	NA	-38.4	NA	NA	NA	NA	NA	NA	NA
Blankenship Fee 4-8 (FU) (g)	-----	-----	------	-----	-----	NA	-38.08	NA	NA	NA	NA	NA	NA	NA
Phase II														
Tribal Pavillion 14-10 (WR) (PGPP01)	-----					NA	-38.75^{I}	-203.4^{I}	-26.93^{I}	-162.5^{I}	-24.93^{I}	-147.2^{I}	-25.83^{I}	-25.26^{I}
Tribal Pavillion 43-10 (FU) (PGPP02)	-----					NA	-39.07^{I}	-212.99^{I}	-25.99^{I}	-157.5^{I}	-19.40^{I}	NA	NA	-23.87^{I}
Tribal Pavillion 24-2 (WR) (PGPP04)	-----					NA	-39.26^{I}	-204.9^{I}	-26.79^{I}	-166.2^{I}	-25.33^{I}	-148.0^{I}	-25.66^{I}	-25.05^{I}
Tribal Pavillion 33-10 (FU) (PGPP05)	-----					NA	-39.05^{I}	-207.3^{I}	-26.21^{I}	-161.1^{I}	-18.46^{I}	-101.7^{I}	-23.96^{I}	-23.64^{I}
Tribal Pavillion 14-2 (FU) (PGPP06)	-----					NA	-39.28^{I}	-215.3^{I}	-26.42^{I}	-162.3^{I}	-24.01^{I}	-145.2^{I}	-25.33^{I}	-24.87^{I}
MW01														
EPA Phase III	0.3	16.0^{S}	2.23^{S}	0.79^{S}	0.158^{S}	NA	-38.89^{I}	-191.3^{I}	-26.55	NA	-23.85^{I}	NA	NA	NA
EPA Phase III(g)	-----	-----	------	-----	-----	$<0.2^{I}$	-39.44^{I}	-209.1^{I}	-26.63	-165.0^{I}	-23.76^{I}	-143.7^{I}	NA	NA
EPA Phase IV	0.7	17.93^{S}	2.95^{S}	1.25^{S}	$0.172(J)^{S}$	NA	-38.88^{I}	-211.6^{I}	-26.70	NA	-24.40^{I}	NA	-25.3^{I}	-24.4^{I}
EPA Phase IV(g)	-----	-----	------	-----	-----	NA	-39.25^{I}/ -39.28^{I}	-211.2^{I}/ -210.1^{I}	-26.67^{I}/ -26.67^{I}	-166.8^{I}/ -167.4^{I}	-23.74^{I}/ -23.91^{I}	-146.1^{I}/ -146.6^{I}	NA	NA
USGS Phase V	1.6-3.0	$27.5^{T}/30.5^{T}$ $26^{UC}/26^{UC}$	$3.6(J+)^{T}$/ $4.0(J+)^{T}$	1.4^{T}/ 1.3^{T}	NA	2.22^{W}	NA	NA	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-4	1.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EPA Phase V 0412	1.8	$17.3^{S}/17.3^{S}$	2.38^{S}/ 2.21^{S}	0.763^{S}/ 0.663^{S}	0.199^{S}/ 0.169^{S}	NA	-38.2^{I}	-205.3^{I}	-26.5^{I}	NA	NA	NA	NA	NA
EPA Phase V 0412-2	2.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-3	2.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-5	2.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-7	2.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-6	2.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-8	2.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-9	3.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
USGS Phase V	3.0	$25.5^{T}/27.0^{T}$ 28^{UC}	$3.2(J+)^{T}$/ $3.3(J+)^{T}$	1.1^{T}/ 1.0^{T}	NA	1.53^{W}	-38.54^{I}	-208.0^{I}	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-10	3.3	18.8^{S}	18.8^{S}	0.715^{S}	0.184^{S}	NA	-38.5^{I}	-205.9^{I}	-26.6^{I}	NA	NA	NA	NA	NA
MW02														
EPA Phase III	0.1	18.99^{S}	3.20^{S}	1.82^{S}	NA	NA	-41.83^{I}	-203.8	-26.4^{I}	NA	-24.28^{I}	NA	NA	NA
EPA Phase III(g)	-----	-----	------	-----	-----	$<0.2^{I}$/ $<0.2^{I}$	-41.85^{I}/ -41.72^{I}	-209.4^{I}/- 209.2^{I}	NA	NA	NA	NA	NA	NA
EPA Phase IV	0.6	18.82^{S}	2.55^{S}	2.26^{S}		NA	-41.30^{I}/ -41.37^{I}	-210.7^{I}/ -208.2^{I}	-26.25^{I}/ -26.28^{I}	NA	-24.29^{I}/ -24.28^{I}	NA	-25.3^{I}/ -25.3^{I}	-24.3^{I}/ -24.5^{I}
EPA Phase IV(g)	-----	-----	------	-----	-----	NA	-41.05^{I}/ -41.01^{I}	-208.9^{I}/ -210.8^{I}	-26.10^{I}/ -26.09^{I}	-170.5^{I}/ -171.4^{I}	-24.05^{I}/ -24.06^{I}	NA	NA	NA
EPA Phase V 0412-1	0.0	19.10^{S}	3.06^{S}	1.58^{S}	0.380^{S}	NA	-41.2^{I}	-209.1^{I}	-26.2^{I}	NA	NA	NA	NA	NA
EPA Phase V 0412-2	1.0	22.00^{S}	3.07^{S}	1.78^{S}	0.517^{S}	NA	-41.2^{I}	-199.6^{I}	-26.3^{I}	NA	NA	NA	NA	NA
USGS Phase V 0412-2	1.0	32.00^{S}	4.90^{S}	2.20^{S}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

BH - Borehole
S – Shaw Environmental
T – Test America
UC – USGS Reston Chlorofluorocarbon Laboratory
W – Woods Hole Oceanogrpahic Institute

Table SI E6. Dissolved Inorganic Carbon, Water Isotopes, Tritium, SF_6, and He in MW01 and MW02

	Borehole Volumes	DIC (mg/L)	δ^{13}DIC (‰)	δ^{2}H (‰)	δ^{18}O (‰)	Tritium (pCi/L)	SF_6 (fg/kg)	He (10^{-9} cm^3/g water)	Rn-222 (pCi/L)	Rn-226 (pCi/L)	Rn-228 (pCi/L)
MW01											
EPA Phase III	0.3	26.9^{O}	-12.18^{I}	-113.8^{I}	-13.8^{I}	NA	NA	NA	NA	NA	NA
EPA Phase IV	0.7	12.7^{O}	-12.01I	-109.5^{I}	-13.3I	NA	NA	NA	NA	NA	NA
USGS Phase V	1.6-3.0	20^{T}/19^{T}	-14.39^{W}	-113^{US}/ -113^{US}	-13.32^{US}/ -13.32^{US}	0.60^{UM}	<1.00^{UC}	1170^{UC}/ 1190^{UC}	1060^{U}	0.087^{E}	0.16(R)^{E}
EPA Phase V 0412-4	1.6	NA	NA	-112.9^{I}	-13.3^{I}	NA	NA	NA	NA	NA	NA
EPA Phase V 0412	1.8	15.2^{O}/ 15.2^{O}	-11.70^{I}/ 12.13^{I}	-113.1^{I}/ -113.0^{I}	-13.2^{I}/ -13.3^{I}	<0.80^{I}/ <0.80^{I}	NA	NA	NA	NA	NA
EPA Phase V 0412-2	2.1	NA	NA	-113.0^{I}	-13.3^{I}	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-3	2.3	NA	NA	-113.0^{I}	-13.3^{I}	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-5	2.4	NA	NA	-113.1^{I}	-13.3^{I}	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-7	2.6	NA	NA	-113.2^{I}	-13.3^{I}	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-6	2.7	NA	NA	-113.2^{I}	-13.4^{I}	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-8	2.9	NA	NA	-113.3^{I}	-13.4^{I}	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-9	3.0	NA	NA	-113.4	-13.3^{I}	NA	NA	NA	NA	NA	NA
USGS Phase V	3.0	21^{T}	-14.11^{W}	-113^{US}	-13.39^{US}	0.30^{UM}	<1.00^{UC}	2940^{UC}	NA	0.100^{E}	0.23^{E}
EPA Phase V 0412-10 3.3		19.1^{O}	-11.94^{I}	-113.6^{I}	-13.3^{I}	<0.80^{I}	NA	NA	NA	NA	NA
MW02											
EPA Phase III	0.1	20.4^{O}	NA	-117.4^{I}	-14.6^{I}	NA	NA	NA	NA	NA	NA
EPA Phase IV	0.6	1.40^{O}/ 1.39^{O}	DIC too low	-113.4^{I}/ -113.5^{I}	-14.2^{I}/ -14.3^{I}	NA	NA	NA	NA	NA	NA
EPA Phase V 0412-1	0.0	1.25^{O}	DIC too low	-116.3^{I}	-14.2^{I}	<0.80^{I}	NA	NA	NA	NA	NA
EPA Phase V 0412-2	1.0	2.26^{O}	DIC too low	-116.8^{I}	-14.2^{I}	<0.80^{I}	NA	NA	NA	NA	NA
USGS Phase V 0412-2 1.0		4.6^{T}	NA	NA	NA	NA	NA	NA	NA	NA	NA

E - Eberline Laboratory (contractor to USGS)
I – Isotech
U - U.S. Geological Survey National Water Quality Laboratory
UC – USGS Restn Chlorofluorocarbon Laboratory
UM – USGS Menlo Park Tritium Laboratory
US – USGS Reston Stable Isotope Laboratory
W – Woods Hole Oceanogrpahic Institute

E.5 Discussion of Potential Cement-pH Interaction

Elevated pH levels (>11 standard units) were observed during purging and sampling at MW01 and MW02 during Phase III, IV and V sampling events (Figure SI E5). During a period of extensive purging at MW01 (over 5000 L) during the Phase V sampling event, specific conductance decreased from 3.93 to 1.31 mS/cm before stabilizing and pH decreased from 12.14 to 10.70.

Simulations were conducted to evaluate whether trends in pH and specific conductance were due to insufficient purging. Observed specific conductance and pH as a function of time during the Phase V sampling event; calculated casing, borehole, and screen exchange volumes; estimated fraction of stored casing water in the sampling train; and simulated sample train/formation concentration ratios (C_P/C_F) as a function of hypothetical initial screen/formation concentration ratios (C_0/C_F) and initial casing/formation concentration ratios (C_C/C_F) are illustrated in Figure SI E6a. In all calculations, the initial concentration in the screen (C_0) was set equal to casing concentration (C_C) or $C_0/C_F = C_C/C_F$. Pumping rate and observed drawdown are illustrated in Figure SI E6b.

Simulations indicated that the fraction of casing to formation water entering the sampling train at MW01 during the Phase V sampling event fell below 0.1% at 0.81 borehole volumes and was at 0.003% during the time of first EPA sample collection during the Phase V sampling event. During purging, there were 26 screen exchange volumes (casing volume of screen plus annular space outside screen). Regardless of the initial hypothetical condition, when C_0/C_F and C_C/C_F were less than unity (i.e., initial concentration in casing and well screen less than surrounding formation), sampling train concentration reached 99% of formation concentration by 0.81 borehole exchanges. When initial hypothetical values of C_0/C_F and C_C/C_F were set at values greater than unity (initial concentration in casing and well screen greater than the surrounding formation due to potential well construction effects), sample train concentration reached 101% constant formation concentration by 1.26, 1.48, 1.65, and 1.84 borehole volumes for C_0/C_F and C_C/C_F values of 1.5, 3, 10, and 100, respectively. When C_0/C_F and C_C/C_F was set to an extreme value of 1000, sample train concentration reached 101% constant formation concentration by 2.27 borehole volumes. Thus, trends in pH observed during purging are due to interaction with formation media, not the wellbore.

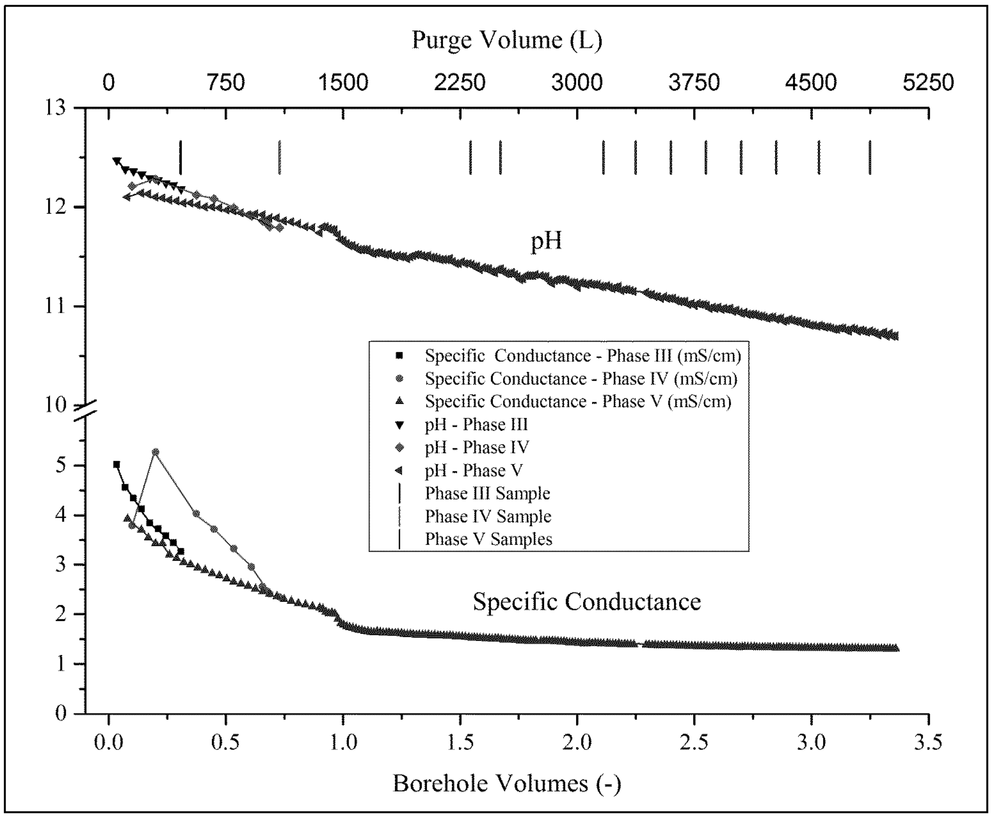

Figure SI E5. Trends in pH and specific conductance during purging at MW01 during Phase III, IV, and V sampling events as a function of purge volume and borehole volumes (1 borehole volume ~ 1500 L). Times of sample collection illustrated by straight bars

pH declined during purging during all three sampling events in an approximately linear fashion (Figures SI E6). Specific conductance declined rapidly and then stabilized after approximately one borehole volume. If reduction in pH and specific conductance were due to dissolved solids remaining in well casing as a result of drilling and/or well construction materials, this would correspond to C_0/C_F =

C_C/C_F values between 10 - 100 for pH and 3 for specific conductance. Reduction in pH and specific conductance and pH during purging occurred much more slowly than would be expected if dissolved solids remained in well casing as a result of well construction effects.

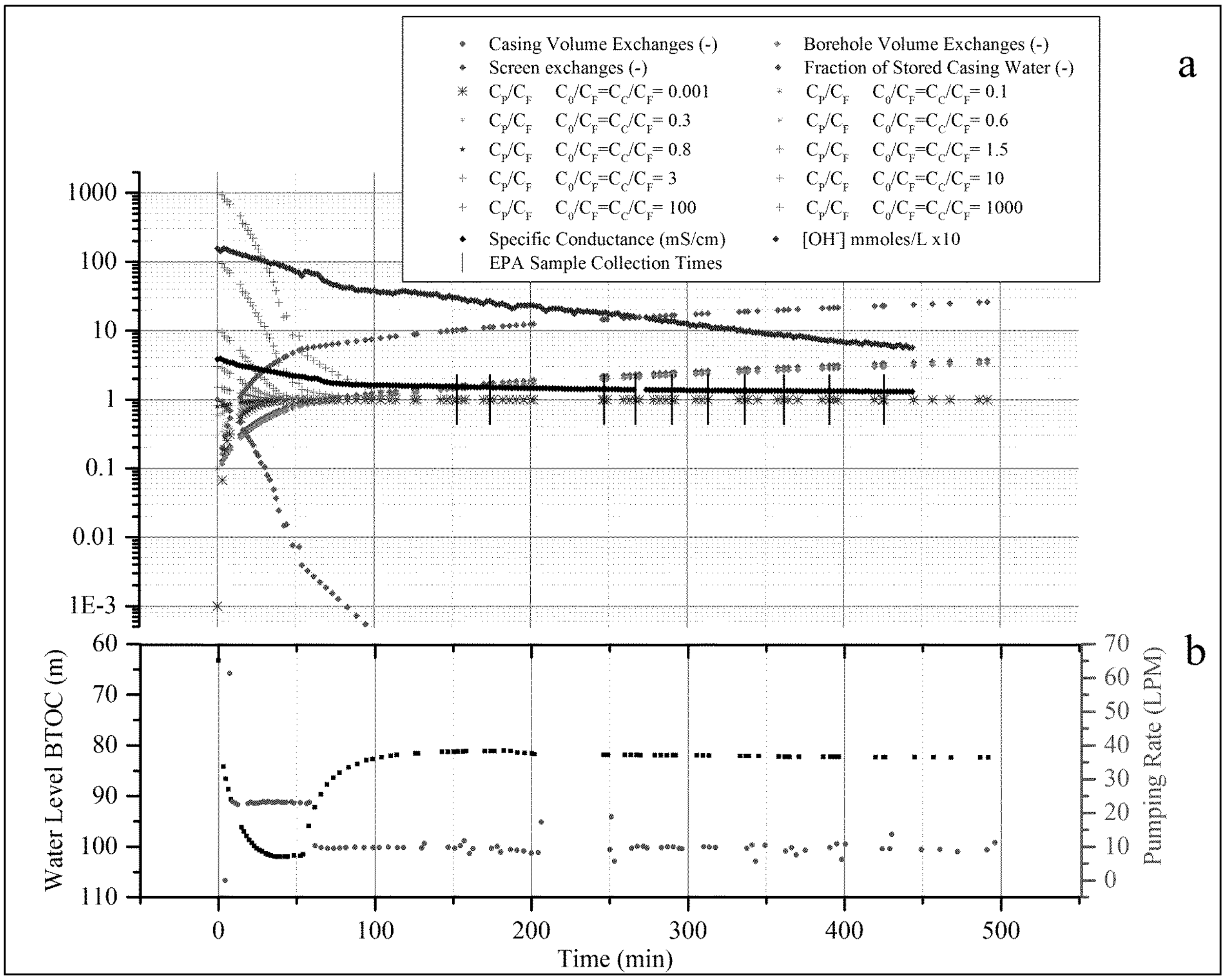

Figure SI E6. (a) Observed decrease in pH (in mmoles/L) and specific conductance during purging as a function of time during the Phase V sampling event in MW01. Increase in casing volumes (up to 3.8), borehole volumes (up to 3.4), and screen exchanges (up to 26), and EPA sample collection times (approximately 30 minutes in duration) illustrated. Simulation of fraction of store casing water in sample train (0.003% at first sample collection), sample train (C_P) / formation (C_F) concentration ratios as a function of initial screen C_0 and casing C_C /formation (C_F) concentration ratios using a casing plug flow – screen mixing wellbore process model illustrated. (b) Rise in water level in well casing as a result of reduced pumping rate in MW01 during Phase V sampling.

The pH of produced water samples varied from 5.6 to 9.0 standard units (Figure SI E7a). However, pH measurements from produced water samples were primarily from production wells where CO_2 foam was used for hydraulic fracturing. There was substantial variation in hydraulic fracturing practices over time and throughout the field. Potassium hydroxide (KOH) was used for hydraulic fracturing. In ground water having sodium - sulfate ($Na\text{-}SO_4$) type composition, small quantities of KOH addition could result in pH approaching 12 units[27]. Water flowing to the surface at Tribal Pavillion 13-1 during Bradenhead testing had a pH of 10.86 and nearly all Bradenhead gas samples were devoid of CO_2 (Table SI D3) suggesting elevated pH above intervals of stimulation. There was also an anomalous trend of increasing pH with depth in domestic wells (Figure SI E7b).

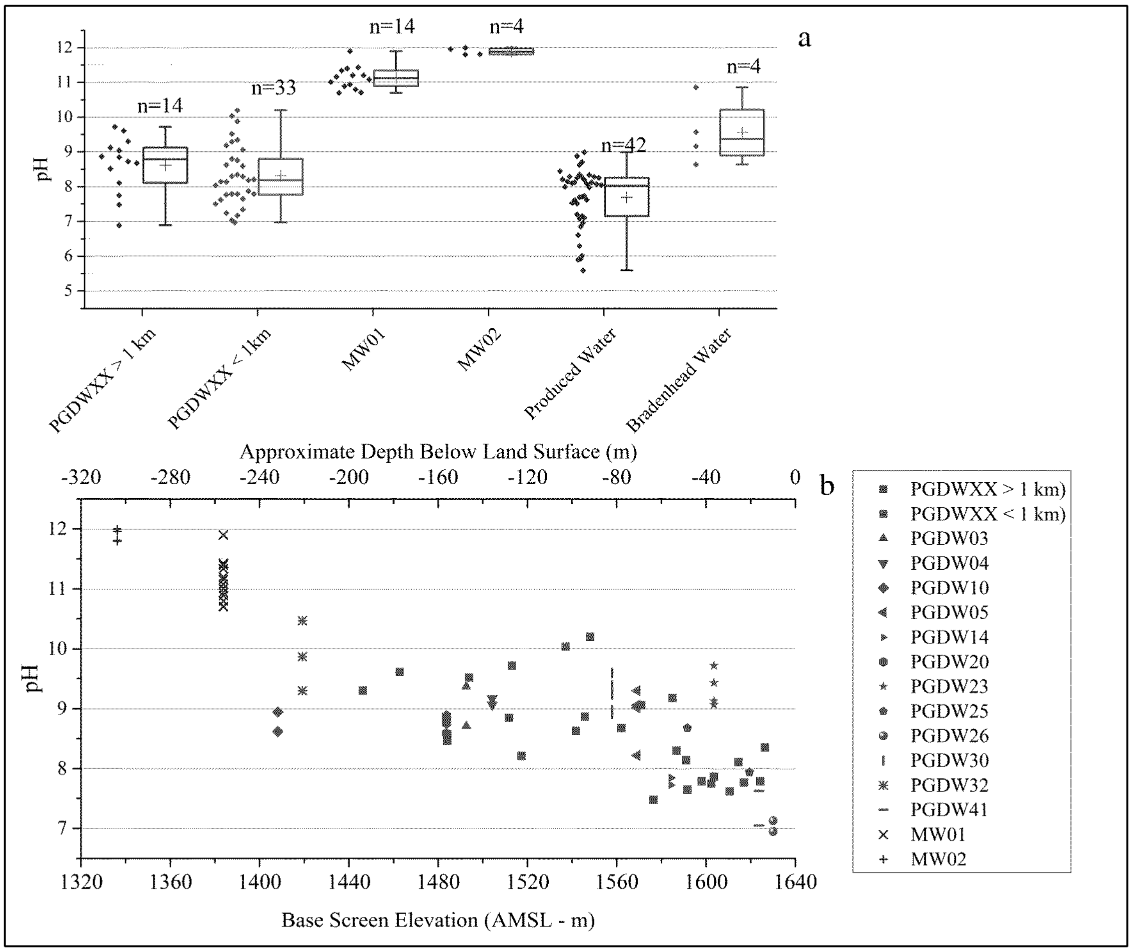

Figure SI E7. (a) Box and whisker plots of minimum, quartiles, median (line), mean (cross), and maximum values of pH of domestic wells (PGDWXX) greater than 1 km from a production well, domestic wells less than 1 km from a production wells, MW01, MW02, produced water, and Bradenhead water samples. Mean values are represented for domestic well locations sampled more than once. Produced water and bradenhead locations were sampled once. Measurement at MW01 and MW02 represent samples collected during Phase III, IV, and V sample events to illustrate variability. (b) pH levels in domestic wells (PGDWXX) less than and greater than 1 km of a production well (red and blue respectively) and monitoring wells as a function of absolute mean seal level (AMSL). All data points are illustrated for locations sampled more than once.

Water from MW01 and MW02 was highly undersaturated with respect to portlandite ($Ca(OH)_2$) at -4.3 and -2.3 during the Phase V sampling event, respectively. Water in contact with hydrating cement is saturated or oversaturated (saturation index greater than 0) to portlandite[67-69] and remains oversaturated prior to degradation (e.g. carbonation)[70-73]. Calcium concentrations in MW01 and MW02 were typical of domestic wells (Figure SI E8a) displaying random scatter with depth (Figure SI E8b). Calcium concentrations should be significantly elevated in the presence of cement interaction[74].

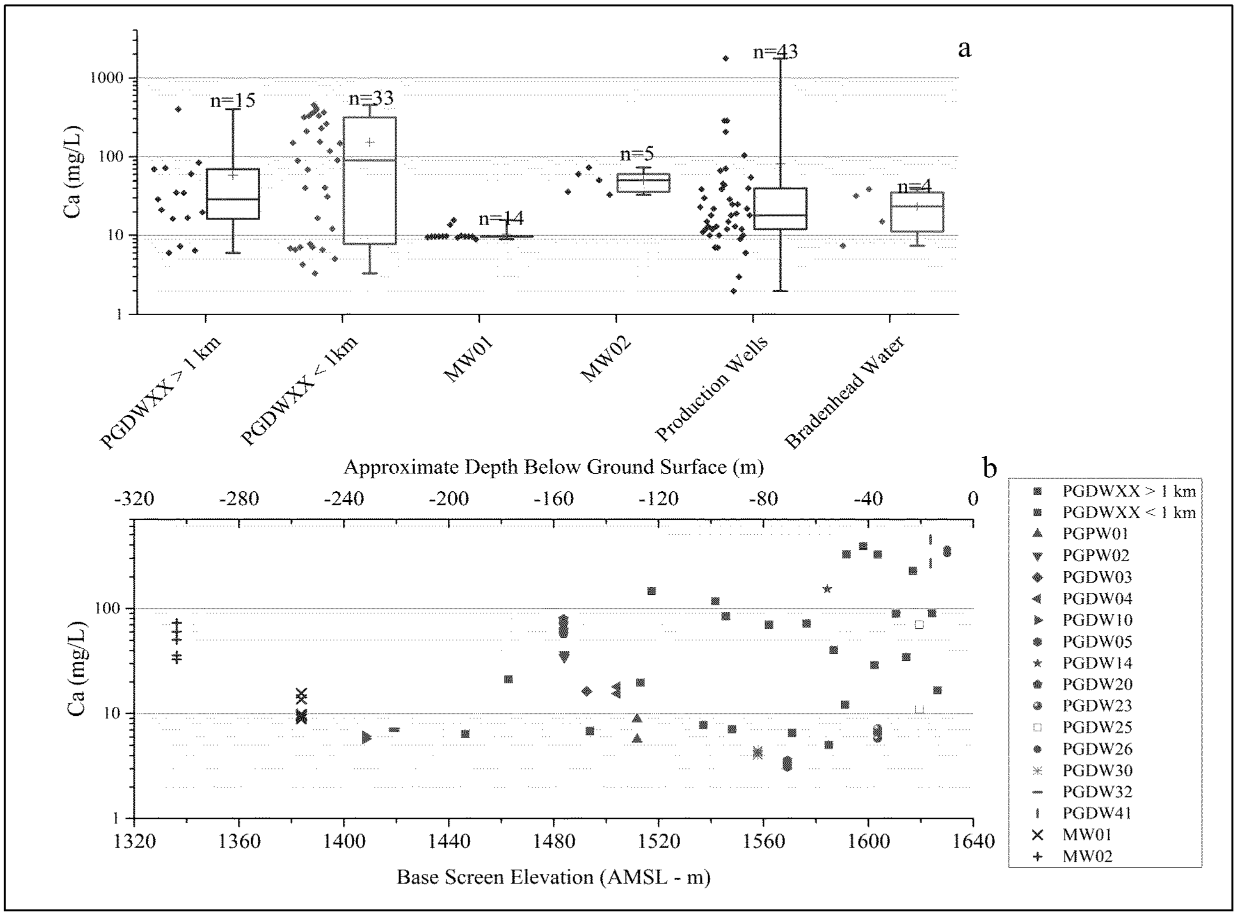

Figure SI E8. (a) Box and whisker plots of minimum, quartiles, median (line), mean (cross), and maximum values of Ca of domestic wells (PGDWXX) greater than 1 km from a production well, domestic wells less than 1 km from a production wells, MW01, MW02, produced water, and Bradenhead water samples. Mean values are represented for domestic well locations sampled more than once. Produced water and bradenhead locations were sampled once. Measurement at MW01 and MW02 represent samples collected during Phase III, IV, and V sample events to illustrate variability. (b) Ca levels in domestic wells (PGDWXX) less than and greater than 1 km of a production well (red and blue respectively) and monitoring wells as a function of absolute mean seal level (AMSL). All data points are illustrated for locations sampled more than once.

Another explanation of elevated pH in MW01 at the start of purging with decrease during purging could be progressive intake of formation water more distal from the screen that has undergone less degassing. Water underwent vigorous degassing and foaming during purging at MW01 and MW02 indicating total dissolved gas pressure (TDGP) significantly above atmospheric pressure (Figure SI E9). During the Phase IV sampling event, pump cavitation occurred at MW02 after removal of 1287 L of water with 40 m of hydrostatic head from the base of the borehole indicating 4.7 atm or 0.48 MPa TDGP (atmospheric pressure = 0.86 atm). Degassing in the immediate vicinity of the borehole could result in removal of carbon dioxide and conversion of bicarbonate/carbonate to non-carbonate alkalinity:

$$HCO_3^- \rightarrow CO_{2(g)} + OH^-$$

$$CO_3^{2-} + H_2O \rightarrow CO_{2(g)} + 2OH^-$$

During purging at MW01 in the Phase V sampling event, DIC increased from 15.2 to 19.1 mg/L as pH decreased from 11.34 to 10.71. During development of MW01 in August 2010, prior to gas entry, documented by measurement of lower explosive levels in well casing, pH varied from 8.72 to 9.06 standard units during removal of 33,300 L of water.

Figure SI E9. Photograph of foam in YSI flow cell during purging at MW01

E.6 Discussion of Potential Cement-Potassium Interaction

Similar to pH, elevated potassium may be the result of interaction with cement. Alkalis in cement are present as readily soluble sulfates (K_2SO_4 and Na_2SO_4) and less soluble oxides (K_2O and Na_2O) in the major clinker minerals[70-72,75] leading to high alkali and sulfate concentrations during the first hours of hydration[76].

Potassium and calcium concentrations were positively correlated in domestic well and monitoring wells with apparent random scatter in bradenhead and produced water samples (Figure SI D1). With exception of EPA monitoring wells, potassium concentrations generally decreased with depth (Figure SI 10a) which was reduced to random scatter when potassium was normalized by calcium concentrations (Figure SI E10b).

Potassium concentrations decreased during purging at MW01 during the Phase V sampling event while calcium, silicon, chloride, and fluoride remained fairly constant or decreased at a slower rate (Figure SI E11a). Concentrations of sodium and strontium decreased (Figures SI E12b, c) while sulfate increased during purging (Figures SI E11b). Given that soluble sulfates are associated with curing of cement, sulfate concentrations should decrease rather than increase during purging. Unlike potassium but similar to calcium, strontium did not decrease during purging during the Phase V sampling event but decreased compared to Phase III and Phase IV sampling events (Figure SI 11c) potentially indicating temporal variability rather than interaction with cement.

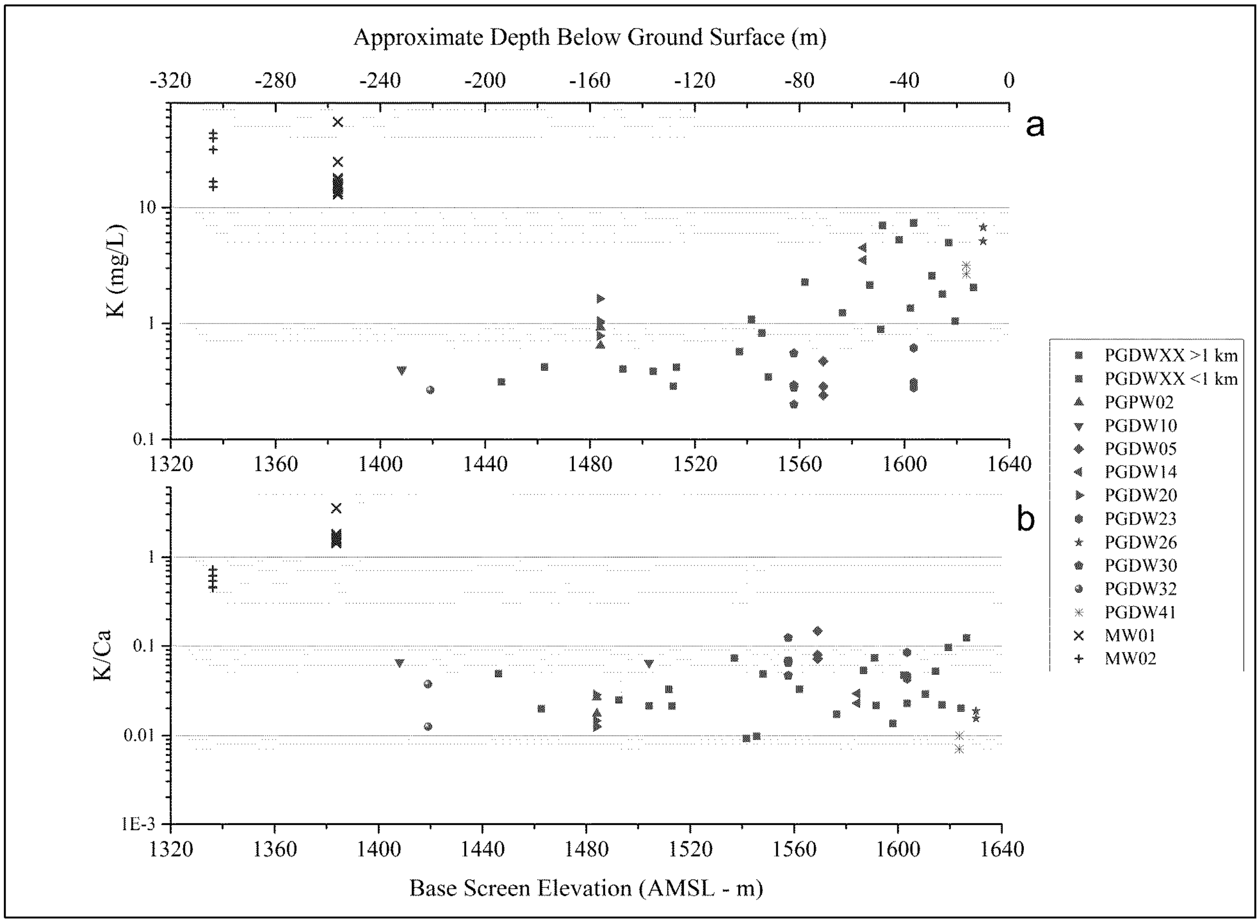

Figure SI E10. (a) Potassium concentration and (b) potassium/calcium concentration ratios for domestic wells (PGDWXX) less than and greater than 1 km of a production well, monitoring wells MW01 and MW02, production wells, and bradenhead samples as a function of absolute mean sea level (AMSL). Domestic wells are identified when sampled more than once.

E.7 Discussion of Potential Cement-Glycol Interaction

Polar organic compounds, including diethylene glycol (DEG) are used to reduce the energy required to grind clinker material for cement[77-80]. Thus, it is plausible that detection of glycols in monitoring wells is due to interaction with cement. Smith et al.[81] determined bulk concentrations of glycols and 2-butoxyethanol (2-BE), and a number of selected organic compounds in 5 Type I/II Portland cement samples and conducted a 5-day leaching study on the cured cement sample having the highest bulk concentrations of glycols. DEG, triethylene glycol (TEG), and tetraethylene glycol (TREG) were detected after the last aqueous exchange at concentrations of 97, 250, and 52 μg/l, respectively. 2-BE was not detected.

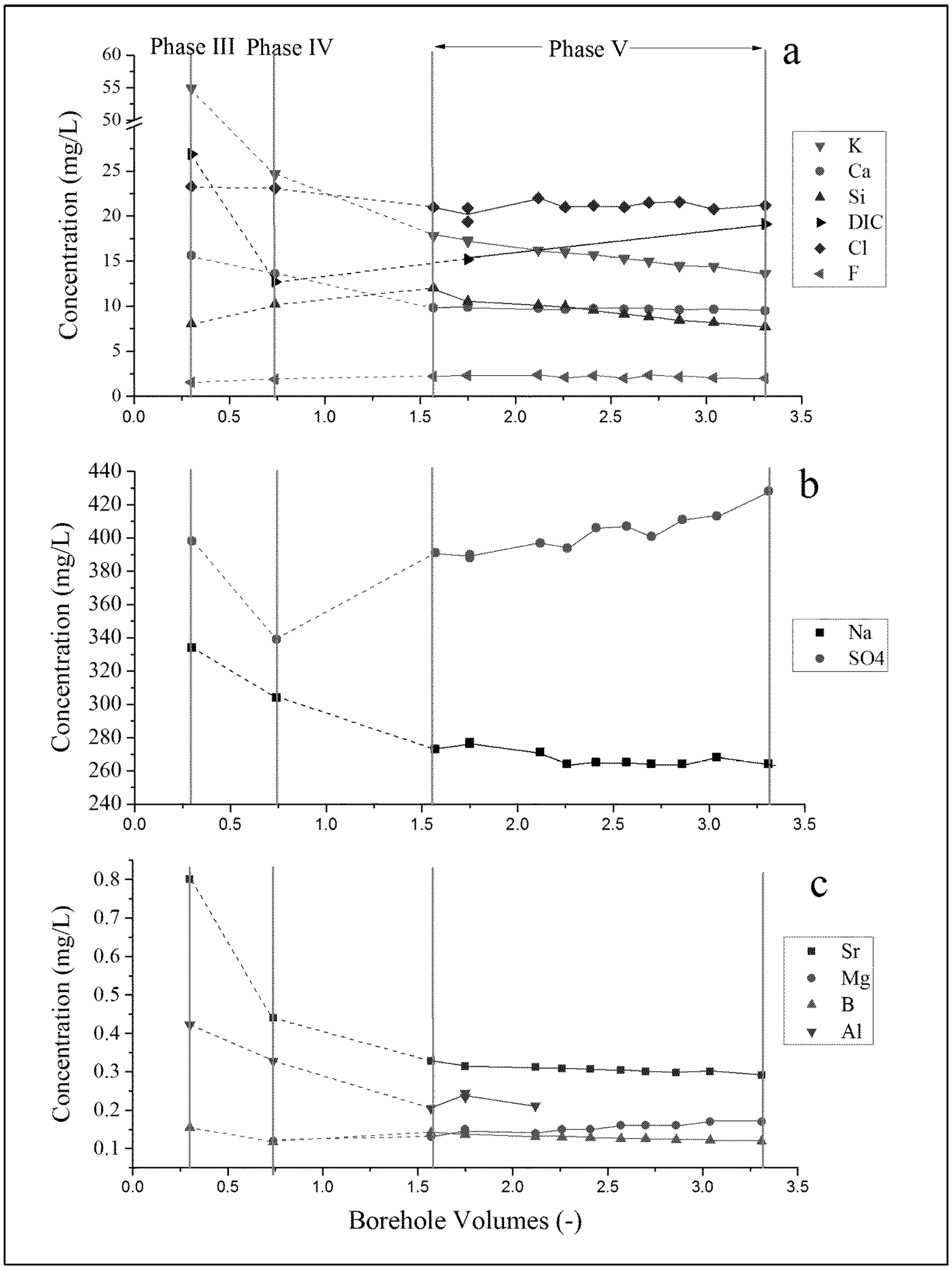

Figure SI E11. Concentration variation of a) potassium (K), calcium (Ca), silicon (Si), dissolved inorganic carbon (DIC), chloride (Cl), and fluoride (F); (b) sodium (Na) and sulfate (SO_4); and (c) Strontium (Sr), magnesium (Mg), boron (B), and aluminum (Al) during purging at MW01 as a function of borehole volume during Phase III, IV, and V sampling events.

During its national study on hydraulic fracturing, EPA conducted analysis of glycols using high performance liquid chromatography with dual mass spectrometry (HPLC-MS/MS) at five retrospective study areas with non-detection at 83 domestic wells sampled[82-86]. Glycols were only detected in a produced water sample[86]. Using HPLC-MS/MS analysis, glycols were detected at domestic wells sampled in the Pavillion investigation. The discrepancy in detection of glycols in leachate and domestic well samples may be due variation in use of cement for domestic well construction, product variability, and exposure factors (i.e. dilution, cross-sectional exposure area, etc.) commonly used to evaluate impact of construction materials on water quality.

In EPA Method 1315[87], a solution to diffusive mass transfer through a semi-infinite media (Crank[88]) is utilized to evaluate mass flux from monolithic samples:

$$Flux = D\rho\left(\frac{\partial C}{\partial x}\right)_{x=0} = \frac{D\rho C_0^*}{\sqrt{\pi D t}}$$

Flux = diffusive flux ($\mu g/m^2$ s)

C_0^* = initial concentration in cement (µg/kg)

ρ = density of cement (kg/m^3)

D = diffusion coefficient of diffusing species (m^2/s)

t = time (s).

Using this approach, concentration in a well during purging (C_{well}) (µg/L) can then be estimated by

$$C_{well} = \frac{(flux)(SA)}{flow}$$

To evaluate mass flux from cement at MW01, an unrealistic worst-case scenario of complete encasement of cement around a 22 cm (8.5") diameter pre-packed screen was assumed (surface area = 4.13 m^2 or 6406 in^2) with bulk DEG concentration of 37,000 µg/kg from Smith et al.[81]. Diffusivity of cured cement was set equal to 10^{-12} m^2/s (EPA 2010b) with density of 1850 kg/m^3 (density of cement varies from 1200 - 2500 kg m^{-3}). An average flow rate of 16 LPM (flow from MW01 during the Phase V sampling event varied from 8 to 24 LPM) was assumed. The hypothetical concentration of DEG in MW01 decreased from 2.0 µg/L at day 1 to below detection at 0.083 µg/L on day 600 - the approximate time for Phase V sampling after curing of cement. Using the maximum bulk concentration determined by Smith et al.[81] for TEG (79,000 µg/kg) a hypothetical concentration of TEG in MW01 decreased from 43.5 µg/L at day 1 to below detection at 0.178 ug/L on day 600.

Glycols decreased during purging in the Phase V sampling. However, compound classes and compounds (GRO, DRO, phenols) not associated with cement also decreased during purging (Figure SI E12) suggesting alternative explanations such as aquifer physical and chemical heterogeneity.

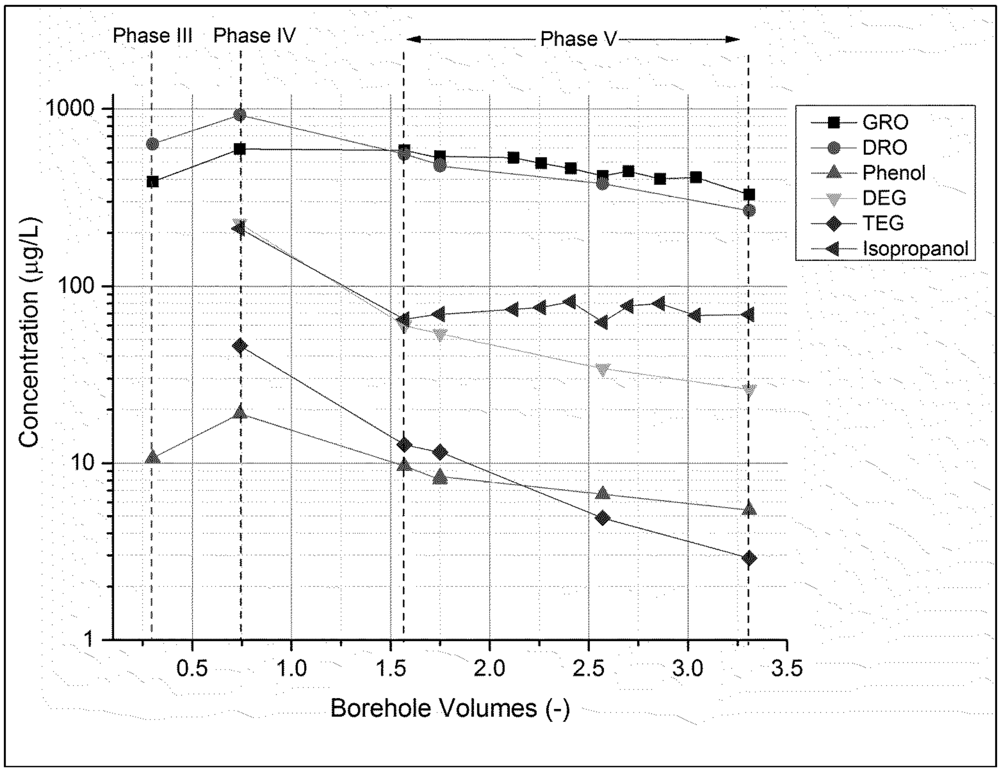

Figure SI E12. Concentration of diethylene glycol (DEG) and triethylene glycol (TEG), as a function of borehole volume during Phase III and IV sampling events and while purging during the Phase V sampling event. Concentrations of gasoline range organics (GRO), diesel range organics (DRO), phenol, and isopropanol included for comparison.

A number of investigators have documented non-uniform concentration trends (increasing or decreasing trends as opposed to erratic variation) during purging[89-94]. Keith et al.[89] identified a number of potential causative factors for observation of solute concentration trends during purging: physical heterogeneity, chemical heterogeneity, screening of wells over multiple water bearing units. Analytical and numerical modeling indicate that concentration trends during purging could be a function of convergent flow[95], lithologic layers of varying hydraulic conductivity[96-98], anisotropy[98], the ratio of hydraulic conductivity of the sandpack (in this case open borehole around pre-packed screen) to surrounding formation[96], well design[98], and boundary conditions[98].

Concentration variation during purging could also be due to vertical ambient borehole flow prior to purging. Vertical ambient flow in long-screened monitoring wells such as MW01 and MW02 is well documented[99-103]. A monitoring well is an open conduit requiring little head differential to induce substantial cumulative flow over an extended period of time between sampling events[94,100,104-106].

Significant solute redistribution can occur at head differentials below the sensitivity currently available instrumentation[104].

Section F - Potential Impact of Unlined Pits on Domestic Wells

Table SI F1. Summary of disposal of drilling mud and production fluids in from production wells

	Unlined Pits Used to Dispose Invert Mud	Unlined Pits Used to Dispose WBM	Unknown Disposal of WBM	Disposal of WBM at Lozier Area	WBM Used on Location †	WBM Disposed in Lined Pits	Offsite Disposal of WBM	Totals
Pits Likely Used for Disposal of Production Fluids	41	3	0	0	0	0	0	44
No Production Fluids	16	4	0	0	0	7	0	27
Offsite Disposal of Production Fluids	0	0	10	8	19	26	47	110
Totals	57	7	10	8	19	33	47	181

WBM – water based mud

† - used to construct berms or spread out on site

Table SI F2. Summary of disposal of drilling mud and production fluids in pits, results of soil and surficial ground-water sampling, volumes of soil excavation, distance and direction of domestic wells with 600 m of pits, review of completion and stimulation record by WOGCC[31] of production wells associated with unlined pits, and recommendations by WOGCC[32] for further or no further investigation.

Production Well Abbreviation	Drilling Mud Used Below Surface Casing	Pit Used or Likely Used to Dispose Drilling Mud and Cuttings Onsite	Pit Used or Likely Used for Disposal of Production Fluids?	Stimulated Prior to Jan 1995?	Number of Soil Screening Locations	Maximum Soil Contamination (mg/kg) and Number of Soil Samples	Excavation Volume (yd^3)	Excavation Criterion (mg/kg TPH)	Number of Ground-Water Sampling Locations	Maximum Ground-Water Contamination in Surficial Deposits (µg/l) and Number of Ground-Water Samples	Surficial Geology	Domestic Wells Within 600 m of Production Wells (Depth, Distance, Direction from Production well)	Stimulation Record Reviewed by WOGCC (2014)	Adequate Site Assessment as Judged by WOGCC (2015)	Further Investigation Recommended by WOGCC (2015)	Comments
MHR 1	"Chem Gel"	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	PGDW41 (31m,314m,NW)	Yes	NI	No	Completed amd P&A in 1953. No production or stimulation.
14-12	Invert	Yes[U]	Yes	Yes	20	GRO:340 (n=23) DRO:4300 (n=23) Benzene: ND (n=20) Toluene: ND (n=20) Ethylbenzene: 0.066 (n=20) Xylenes: 0.085 (n=20)	~1,306	1,000	7	GRO: ND (n=7) DRO: 1,300 (n=7) Benzene: ND (n=7) Toluene: ND (n=7) Ethylbenzene: ND (n=7) Xylenes: ND (n=7)	Qa	PGDW22 (?m,261m,SW) PGDW32 (206m,563m,SE) P22660.0P (53m,407m,SE) P22661.0P (15m,535m SE)	No	VRP	VRP	Acid stimulation in 1960. Hydraulic fracturing in 1964 with "salt water." Well flowed "diesel and load water." Acid stimulation with additives in 1980. No description of where flowback and other production fluids were disposed. No produced water from 1978 (records start) through 1983 (shut-in). Sundry notice in Jan 1998 for offsite disposal of production fluids. Encana waiting approval from WYDEQ for closure.
23-7	Q-Broxin Gel	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	CR UW09/250 (?,361m, NE)	No	NI	Yes	Well completed and P&A in 1961. Q-BROXIN Gel used. Well history missing from well completion report. Production and stimulation unlikely.
W 1	"Gel"	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	?	None	No	NI	No	Well completed and P&A in 1961. Production and stimulation unlikely.
23-2	Invert	Yes[U]	Yes	Yes	10	TPH: ND (n=2)	0	1,000	0	Not sampled	Qa	None	No	No	Yes	Well completed in 1962. Hydraulic fracturing in 1965 – no description. No description of where flowback and other production fluids were disposed. Production records from 1978. No produced water until 2004. Sundry notice for offsite disposal of production fluids in Jan 1998. Two separate pit locations.
22-35	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	?	None	No	NI	No	Completed & P&A in 1963. Stimulation unlikely.
GOL 1	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Well completed in 1963. P&A in 1974. No information available on production or stimulation.
14-1	Invert	Yes[U]	Yes	Yes	5	TPH: 3790 (n=5) (Confirmation sample)	~1,400	2,500 or 4,000	0	Not sampled	Qa	PGDW36 (31m,296m,SW)	No	No	Yes	Well completed in 1963. Hydraulic fracturing with undiluted diesel fuel in 1964. In 1993, acid stimulation. No description of where flowback and other production fluids were disposed. Production records from 1978 with 789 bbls produced water prior to 1993. Sundry notice in 1993 to plug water bearing perforation. Sundry notice in Jan 1998 for offsite disposal of production fluids. Post excavation soil TPH exceeded 4000 mg/kg.
21-8	Invert	Yes[U]	Yes	?	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Well completed in 1963. P&A date unknown. Well history missing from well completion report.
21-5	Invert	Yes[U]	Yes	?	13	TPH: 327 (n=8) (Confirmation sample)	~60	7,000	0	Not sampled	Qa	None	No	Yes	No	Well completed in 1963. No documented stimulation until 1999. Production records from 1978. No produced water until 1995. Sundry notice for offsite disposal of production fluids in Jan 1998.
U 13-13	Invert	Yes[U]	Yes	?	5	TPH: 16 (n=5)	0	1,000	0	Not sampled	?	P60032.0W (26m,99m,W)	No	No	Yes	Well completed in 1963. Information on completion missing from well completion report. Production records from 1978. No produced water until 2007. Sundry notice for offsite disposal of production fluids in Jan 1998.
14-6	Invert	Yes[U]	Yes	?	5	TPH: 1298 (n=5) (Confirmation sample)	120	2,500	0	Not sampled		?	No	?	?	Well completion in 1963. Information on completion missing from well completion report. Production records from 1978. No produced water until 2005. Further investigation by WOGCC dependent on potential presence of nearby domestic well.
32-4	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Completed & P&A in 1963. Stimulation unlikely.
24-14	Invert	Yes[U]	Yes	?	11	TPH: 3910 (n=4)	0	4,000	0	Not sampled	Qa	P59499.0W (34m,330m,NW) P24502.0P (55m,360m, E) PGDW34 (31m,474m, NE)	No	No	Yes	Well completed in 1963. No documented stimulation but completion record not reviewed by WOGCC (2014). Production records from 1978. No produced water until 2004 but sundry notice for offsite disposal of production fluids in Jan 1998.

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Production Well Abbreviation	Drilling Mud Used Below Surface Casing	Pit Used or Likely Used to Dispose Drilling Mud and Cuttings Onsite	Pit Used or Likely Used for Disposal of Production Fluids?	Stimulated Prior to Jan 1995?	Number of Soil Screening Locations	Maximum Soil Contamination (mg/kg) and Number of Soil Samples	Excavation Volume (yd^3)	Excavation Criterion (mg/kg TPH)	Number of Ground-Water Sampling Locations	Maximum Ground-Water Contamination in Surficial Deposits (µg/l) and Number of Ground-Water Samples	Surficial Geology	Domestic Wells Within 600 m of Production Wells (Depth, Distance, Direction from Production well)	Stimulation Record Reviewed by WOGCC (2014)	Adequate Site Assessment as Judged by WOGCC (2015)	Further Investigation Recommended by WOGCC (2015)	Comments
44-20	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Twdr	P9334.0P (6m,430m, SW)	No	NI	Yes	Well completed and P&A in 1964. Stimulation or production unlikely. Further investigation by WOGCC dependent on confirmation of nearby domestic well.
23X-24	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Well completed and P&A in 1964. Stimulation or production unlikely.
44-17	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	PGDW03 (137m,265m,SE) PGDW04 (134m,351m,SE) P120203.0W (137m,255m,W) P23056.0P (116m,255m,W)	No	NI	Yes	Well completed and P&A in 1964. Stimulation or production unlikely. No investigation recommended by WOGCC if no nearby domestic wells.
34-33	Invert	Yes[U]	No	?	0	Not sampled	0		0	Not sampled	?	None	No	NI	No	Well completed in 1964. P&A unknown. No information on stimulation or production.
33X-10	Invert	Yes[U]	Yes	Yes	?	Sample data not available	~560	1,000	0	Not sampled	Qa	PGDW14 (58m,224m,NW) PGDW23 (53m,172m,SE) (PGDW44 229m,102m,NW) P24508.0P (53m,365m,SE)	Yes	No	Yes	Acid stimulation and well completion in 1964. Hydraulic fracturing in 1965 with "salt water…flow to pit." P&A in 1983. Invert mud up to 10% oil. Production records from 1978. No produced water to 1983.
24X-3	Invert	Yes[U]	Yes	Yes	9	GRO: 9,200 (n=15) DRO: 3,300 (n=15) Benzene: 4.2 (n=15) Toluene: ND (n=15) Ethylbenzene: 110 (n=15) Total Xylenes: 750 (n=15) Naphthalene: 8.6 (n=11)	~1,000	1,000	11	GRO: 45,200 (n=38) DRO: 59,000 (n=38) Benzene: 1,960 (n=38) Toluene: 0.17 (n=38) Ethylbenzene: 950 (n=38) Xylenes: 4,200 (n=38) Naphthalene: 267 (n=10)	Qa	P66345.0W (21m,258m,NW)	No	VRP	VRP	Well completed in 1965. Acid stimulation with solvent in 1966. No description of where flowback and other production fluids were disposed. Production records from 1978 with 9 bbls produced water in 1986 and increasing to 9,653 bbls after 1995. Invert mud up to 55% oil. Sundry notice for offsite disposal of production fluids in Jan 1998. Ground water monitoring ongoing. A remedial alternatives evaluation report is being drafted by Encana.
14-11	Invert	Yes[U]	Yes	?	12	GRO: 7,400 (n=13) DRO: 7,800 (n=13) Benzene: ND (n=4) Toluene: ND (n=4) Ethylbenzene: 5.1 (n=4) Total Xylenes: 5.1 (n=4) Naphthalene: 15 (n=6)	~940	1,000	8	GRO: 91,100 (n=79) DRO: 78,000 (n=79) Benzene: 476 (n=79) Toluene 15 (n=79) Ethylbenzene: 60 (n=79) Xylenes: 68 (n=79) Naphthalene: 486 (n=46)	Qa	PGDW46 (15m,119m,W) P31805.0W (31m,132m,SE) P69549.0W (31m,132m,SE) (Same well?)	No	VRP	VRP	Well completed in 1965. Well completion report and information on stimulation not available. Production records from 1978. No produced water until 2005 but sundry notice for offsite disposal of production fluids in Jan 1998. Remedial Agreement submitted to WOGCC entailing limited additional soil excavation and ground water monitoring by Encana.
13-13	"Chem Gel"	Yes[U]	Yes	Yes	0	Not sampled	0		0	Not sampled	?	None	No	NI	No	Well completed in 1966. P&A date unknown. Hydraulic fracturing with undiluted diesel fuel, 15% HCl, and 4% "salt water" in 1965. No description of where flowback and other production fluids were disposed.
31-15	Invert	Yes[U]	Yes	?	12	TPH: 70 (n=6) (Confirmation sample)	~1,500	5,500	0	Not sampled	Qa	PGDW11 (107m,230m,NE)	No	?	?	Well completed in 1968. Information on completion missing. Production records from 1978 with 8 bbls produced water in 1988 and increasing to 1,493 bbls after 2004. No description of where produced water was disposed. Sundry notice for offsite disposal of production fluids in Jan 1998. Recommendation of further investigation pending - no soil sample in area with highest PID reading (WOGCC 2015)
32-9	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	PGDW42 (61m,375m,NW)	Yes	NI	Yes	Well completion and P&A after in 1968. No apparent stimulation or production. Investigation recommended by WOGCC because of proximity to a domestic well.

Production Well Abbreviation	Drilling Mud Used Below Surface Casing	Pit Used or Likely Used to Dispose Drilling Mud and Cuttings Onsite	Pit Used or Likely Used for Disposal of Production Fluids?	Stimulated Prior to Jan 1995?	Number of Soil Screening Locations	Maximum Soil Contamination (mg/kg) and Number of Soil Samples	Excavation Volume (yd^3)	Excavation Criterion (mg/kg TPH)	Number of Ground-Water Sampling Locations	Maximum Ground-Water Contamination in Surficial Deposits (µg/l) and Number of Ground-Water Samples	Surficial Geology	Domestic Wells Within 600 m of Production Wells (Depth, Distance, Direction from Production well)	Stimulation Record Reviewed by WOGCC (2014)	Adequate Site Assessment as Judged by WOGCC (2015)	Further Investigation Recommended by WOGCC (2015)	Comments
WEL	"Chem Gel"	Yes^{U}	Yes	Yes	8	GRO: ND (n=8) DRO: 390 (n=8) BTEX: not analyzed Naphthalene: 0.22 (n=1)	0	1,000	2	GRO: < 0.1 mg/l (n=2) DRO: 0.32 mg/l (n=2) BTEX: <1 - <5 µg/l (n=2) Naphthalene: <1 µg/l (n=2)	Qa	PGDW30 (79m,361m,SE) PGDW40 (67.1m,470m,NE)	Yes	Yes	No	Well completed in 1972. P&A in 1981. Acidized in Frontier formation with HCl and KCl solutions in 1971. Potential wellhead leak and discharge to "pits" discussed in memorandum in 1980. Encana (2015) stated that a pit could not be identified.
41X-10	Invert	Yes^{U}	Yes	Yes	7	GRO: ND (n=1) DRO: ND (n=1) Sample data not in well file	0		2	GRO: ND (n=2) DRO: ND (n=2) BTEX: ND (n=2) Sample data not in well file	Qa	PGDW30 (79m,273m,N) PGDW49 (15m,335m,E)	Yes	No	Yes	Well completed in 1973. P&A in 1981. Invert mud contained up to 78% oil while drilling. In 1973 and 1979, hydraulic fracturing with KCl water, gelled KCl, solvents, surfactants, and N_2 foam. No description of where flowback and production fluids were disposed. P&A due to parted casing and water production. No production record.
41X-2	Invert	Yes^{U}	Yes	?	6	TPH: 1190 (n=2)	0	2,500	0	Not Sampled	Qa	None	No	Yes	No	Invert mud up to 76% oil. No documented stimulation or gas production. Sundry notice for offsite disposal of production fluids in Jan 1998.
31X-3	Invert	Yes^{U}	Yes	?	17	GRO: 66 (n=24) DRO: 1200 (n=24) Benzene: ND (n=18) Toluene: ND (n=18) Ethylbenzene: ND (n=18) Xylenes: ND (n=18) Naphthalene: 0.34 (n=1)	~4,392	1,000	5	GRO: 300 (n=5) DRO: 2,700 (n=5) Benzene: ND (n=5) Toluene: ND (n=5) Ethylbenzene: 2.4 (n=5) Xylenes: ND (n=5) Naphthalene: ND (n=1)	Qa	P197335.0W (?,301m,NW) P197336.0W (?,304m,NW)	No	Yes	No	Well completed in 1973. No documented stimulation until 2001. Production record from 1983 with 29 bbls in 1986 and 1987. No description of where produced water was disposed. Increased to 1,215 bbls after 2004. Sundry notice for offsite disposal of production fluids in Jan 1998.
42X-11	Invert	Yes^{U}	Yes	?	8	GRO: 580 (n=11) DRO: 450 (n=11) Benzene: ND (n=11) Ethylbenzene: 0.52 (n=11) Toluene: ND (n=11) Xylenes: 1.1 (n=11) Naphthalene: 0.58 (n=2)	~900	1,000	7	GRO: 50,000 (n= 59) DRO: 31,000 (n=59) Benzene: 240 (n=55) Toluene: 25 (n=55) Ethylbenzene: 240 (n=55) Xylenes: 620 (n=55) Naphthalene: 236 (n=32)	Qa	None	No	VRP	VRP	Well completed in 1974. No documented stimulation but completion record not reviewed by WOGCC (2014). Production record from 1983 with 9 bbls produced water in 1986. No description of where produced water was disposed. Increased to 222 bbls after 2004. Sundry notice for offsite disposal of production fluids in Jan 1998. Encana evaluating alternatives for final remedy and ground water monitoring.
42X-12	Invert	Yes^{U}	Yes	Yes	5	GRO: ND (n=5) DRO: 1,100 (n=5) BTEX: ND (n=1)	~280	2,500	0	Not sampled	Qa	None	No	Yes	No	Completed in 1974. Acid stimulation in 1974. No description of where flowback and production fluids were disposed. Production record from 1983. No produced water until 2004 after which 295 bbls produced. Sundry notice for offsite disposal of production fluids in Jan 1998.
31X-14	Invert	Yes^{U}	Yes	?	6	TPH: ND (n=5) (confirmation sample)	~260	2,500	0	Not sampled	Qa	PGDW34 (31m,518m,S) P44255.0W (69m,148m,N) P41320.0W (31m,148m,N) P99671.0W (17m,148,N)	No	?	?	Well completion in 1974. No documented stimulation. Production records from 1983 with 6,546 bbls water in Feb 1985, 4 bbls in 1986 and 4 bbls in 1988. No description of where produced water was disposed. After 2007, 7,691 cumulative bbls water. Sundry notice for offsite disposal of production fluids in Jan 1998. Further investigation recommend by WOGCC pending review of pre-excavation samples.
CCD	Invert	Yes^{U}	No	No	0	Not sampled	0		0	Not sampled	Qa	Converted to 9441.0P (177m,45m,W)	No	NI	No	Well completion and P&A after completion in 1974. Stimulation or production unlikely. No evidence of converted well sampled.
TR1-22	Invert	Yes^{U}	Yes	Yes	0	Not sampled	0		0	Not sampled	Qa	PGDW48 (116m,397m,NW) PGDW35 (88m,449m,NW)	No	NI	Yes	Well completion in 1976. Acid stimulation and hydraulic fracturing in 1980. No description of where flowback and production fluids were disposed. P&A 1986. Well production file starts in 1978 with 5,281 bbls produced water between 1978 and 1986
1-21	Invert	Yes^{U}	No	No	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Well completion and P&A in 1976. Stimulation or production unlikely. Investigation recommended by WOGCC pending confirmation of nearby domestic wells. No evidence of former well pad – no further investigation recommended (Encana 2015)

Production Well Abbreviation	Drilling Mud Used Below Surface Casing	Pit Used or Likely Used to Dispose Drilling Mud and Cuttings Onsite	Pit Used or Likely Used for Disposal of Production Fluids?	Stimulated Prior to Jan 1995?	Number of Soil Screening Locations	Maximum Soil Contamination (mg/kg) and Number of Soil Samples	Excavation Volume (yd^3)	Excavation Criterion (mg/kg TPH)	Number of Ground-Water Sampling Locations	Maximum Ground-Water Contamination in Surficial Deposits (µg/l) and Number of Ground-Water Samples	Surficial Geology	Domestic Wells Within 600 m of Production Wells (Depth, Distance, Direction from Production well)	Stimulation Record Reviewed by WOGCC (2014)	Adequate Site Assessment as Judged by WOGCC (2015)	Further Investigation Recommended by WOGCC (2015)	Comments
TP 1	Invert	Yes[U]	Yes	?	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Well completion in 1976. P&A date unknown. No record of stimulation. Well production file starts in 1978 with 5,607 bbls produced water from 1978 to 1980. No description of where produced water was disposed.
1-31	Invert	Yes[U]	Yes	?	0	Not sampled	0		0	Not sampled	?	PGDW06 (116m,341m,SE) PGDW12 (116m,491m,NW)	No	NI	No	Well completion in 1976. P&A in 1977. Well completion report not available.
TU 1	Invert	Yes[U]	Yes	?	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Completed in 1976. P&A in 1982. No record of stimulation but completion record not reviewed by WOGCC (2014). Well production file starts in 1978 with 220 bbls produced water from 1978 to 1982. No description of where produced water was disposed. Encana (2015) states that there is no evidence of former well pad.
4-8	Invert	Yes[U]	Yes	Yes	6	GRO: ND (n=6) DRO: 32 (n=6) Naphthalene: 5.3 (n=3)	0	1,000	2	GRO: 5,200 (n=2) DRO: 13,000 (n=2) Benzene: 110 (n=2) Toluene: 250 (n=2) Ethylbenzene: 240 (n=2) Xylenes: 1,200 (n=2) Naphthalene: 72 (n=2)	Qa	PGDW41 (21m,421m,SE) P66345.0W (21m,407m,SE)	Yes	VRP	VRP	Well completed in Mar 1977. Hydraulic fracturing in 1977 with "gel water" and N_2. No description of where flowback and production fluids were disposed. Production file starts in Jan 1978 with 36,978 bbls water from Jan 1978 to Dec 1993. No description of where produced water was disposed. Encana (2015) drafting report for site closure.
34-13	Invert	Yes[U]	Yes	?	0	Not sampled	0		0	Not sampled	?	P197335.0W (?,632m,SE) P197336.0W (?,626m,SE)	No	NI	No	Well completion in 1977. P&A date unknown. Well production file starts in 1978 with 290 bbls produced water from 1978 to 1979. No description of where produced water was disposed.
T24-11	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Twdr	None	No	NI	No	Well completed and P&A in 1978. Stimulation or production unlikely.
24-4	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Well completed and P&A in 1978. Stimulation or production unlikely.
44-15	Invert	Yes[U]	Yes	Yes	6	TPH: 486 (n=1)	0	5,500	0	Not sampled	Qa	PGDW48 (116m,329m,SW) PGDW35 (88m,374m,W) P108128.0W (116m,115m,W) P146856.0W (116m,115m,W)	No	No	Yes	Well completed in 1978. Acid stimulation in 1976 and 1978 with HCl and KCl solutions. No description of where flowback and production fluids were disposed. Production file starts in 1983. No produced water production from 1983 to 2005. Sundry notice for offsite disposal of production fluids in Jan 1998.
21-11	Invert	Yes[U]	Yes	Yes	?	Sample results not available in pit report (WOGCC 2015) or online.	~100	1,000	?	Sample results not available in pit report (WOGCC 2015) or online.	Qa	PGDW26 (20m,229m,W)	No	VRP	VRP	Well completed 1n 1979. Acid stimulation in 1979 with HCl solution and additives. Hydraulic fracturing in 1979 with "YE4P5D" fluid. No description of where flowback and production fluids were disposed. Production file starts in 1983. No produced water until 2005. Sundry notice for offsite disposal of production fluids in Jan 1998. Soil and ground water sampling data not available. Ground water and additional soil data were collected in October 2014. Encana (2015) is preparing a Supplemental Site Characterization report to recommend site closure.

Production Well Abbreviation	Drilling Mud Used Below Surface Casing	Pit Used or Likely Used to Dispose Drilling Mud and Cuttings Onsite	Pit Used or Likely Used for Disposal of Production Fluids?	Stimulated Prior to Jan 1995?	Number of Soil Screening Locations	Maximum Soil Contamination (mg/kg) and Number of Soil Samples	Excavation Volume (yd^3)	Excavation Criterion (mg/kg TPH)	Number of Ground-Water Sampling Locations	Maximum Ground-Water Contamination in Surficial Deposits (µg/l) and Number of Ground-Water Samples	Surficial Geology	Domestic Wells Within 600 m of Production Wells (Depth, Distance, Direction from Production well)	Stimulation Record Reviewed by WOGCC (2014)	Adequate Site Assessment as Judged by WOGCC (2015)	Further Investigation Recommended by WOGCC (2015)	Comments
12-13	Invert	Yes[U]	Yes	Yes	4	GRO: ND (n=4) DRO: ND (n=4) BTEX: ND (n=1)	0	1,000	0	Not sampled	Qa	PGDW32 (206m,173m,NE) PGDW33 (9m,134m,S) P22662.0P (9m,135m, S) P22660.0P (53m,280m,N)	Yes	No	Yes	Well completed in 1979. Acid stimulation with HCl and KCl solution in 1979. Hydraulic fracturing with "versa gel" in 1981. No description of where flowback and production fluids were disposed. P&A in 2001. Production records from 1983 with 18 bbls produced water between1986-1989. No description of where produced water was disposed. Sundry notice for offsite disposal of production fluids in Jan 1998.
41-9	Invert	Yes[U]	Yes	Yes	13	TPH: 3700 (n=8)	~1,200	4,000	0	Not sampled	Qa	PGDW43 (?,176m,NW)	No	No	Yes	Well completion in 1979. Acid stimulation with HCl, KCl solution and additives in 1979 "flowed to pit." No produced water production until 1999 after which 15,593 bbls produced most of which was after recompletion in 2004. Sundry notice for offsite disposal of production fluids in Jan 1998.
TU 2	Invert	Yes[U]	Yes	Yes	0	Not sampled	0		0	Not sampled	Qa	P24502.0P (55m,466m,NE)	No	NI	No	Well completion, acid stimulation, and P&A in 1979. No description of where flowback was disposed.
22-10	Invert	Yes[U]	Yes	Yes	6	TPH: 201 (n=1)	0	7,000	0	Not sampled	Qa	PGDW14 (58m,399m,E) PGDW44 (229m,508m,E)	Yes	No	Yes	Well completion in 1979. Acid stimulation using HCl and KCl solutions with additives in 1979. "Flowed to pit." Production record from 1983. No produced water until after recompletion in 2005. Sundry notice for offsite disposal of production fluids in Jan 1998.
G1	invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled		PGDW15 (31m,469m,NE) PGDW13 (?,488m,NW)	No	NI	No	Well completion and P&A in 1979. Stimulation or production unlikely.
21-15	Invert	Yes[U]	Yes	Yes	7	GRO: 76 (n=1) DRO: 401 (n=1)	0	8,500	0	Not sampled	Twdr	PGDW47 (148m,350m,N) P120049.0W (148m,384m,N)	Yes	?	?	Well completion in 1979. Acid stimulation with additives in 1979 and 1982."Flw'd to pit" Hydraulic fracturing with "Y-F4PSD" "Flow to pit" in 1979. In letter to BLM dated 8/14/2012 concerning of 1,000 gallons of a 15% HCl solution in "compromised" casing between 735 to 1,105 feet below ground surface. Production records from 1983. No produced water until 2008. Sundry notice for offsite disposal of production fluids in Jan 1998. Further investigation dependent upon consideration of domestic wells.
44-10	Invert	Yes[U]	Yes	Yes	10	TPH: 2920 (n=6)	~60	5,500	0	Not sampled	Qa	PGDW23 (53m,253m,N) PGDW11 (107m,388m, S) P200885.0W (?,199m, E) P24508.0P (53m,306m, N)	No	No	Yes	Invert mud 15-20% water. Well completed in 1979. Acid stimulation in 1979."Flowing to pit avg 4 bpm…bled well to pit" Production records from 1983 with 10 bbls water in 1986. No description of where produced water was disposed. Sundry notice for offsite disposal of production fluids in Jan 1998.
22-12	Invert	Yes[U]	Yes	Yes	8	GRO: 120 (n=9) DRO 850 (n=9) BTEX: ND (n=1)	~40-60	1,000	5	GRO: 2,900 (n=5) DRO: 3,500 (n=5) Benzene: ND (n=5) Toluene: ND (n=5) Ethylbenzene: 120 (n=5) Xylenes: 610 (n=5)	Qa	PGDW20 (140m,172m, SE) LD02 (186m,172m, SE)	Yes	VRP	VRP	Well completion 1980. In 1979 and 1980, acid stimulation with HCl solution and additives. In 1980, hydraulic fracturing with "Titan III-30 gel" and B-11 gel breaker" flushed with 2% KCl solution. No description of where flowback and production fluids were disposed. No produced water until 1995 after which 288 bbls produced. No description of where produced water was disposed. Sundry notice for offsite disposal of production fluids in Jan 1998. Encana (2015) continuing ground water monitoring.
11-14	Invert	Yes[U]	Yes	Yes	5	TPH: 16 (n=5)	0	4,000	0	Not sampled	Qa	P29496.0P (40m,164m, E) P91293.0W (3m,254m, W)	No	No	Yes	Well completion in 1980. Acid stimulation in 1980. No description of where flowback and production fluids were disposed. Production record from 1983. No produced water until 2004 after which 12,722 bbls water produced. Sundry notice for offsite disposal of production fluids in Jan 1998.
16-28	KCl Polymer	Yes[U]	No	?	0	Not sampled	0		0	Not sampled	?	None	No	NI	No	Well completion in 1980. P&A date unknown. Well completion report not available.

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F 1-17	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	P95171.0W (26m,404m,W) P65111.0W (27m,404m,W)	No	NI	Yes	Well completion and P&A in 1980. Stimulation or production unlikely. Recommendation pending confirmation of presence of nearby domestic wells (WOGCC 2015).
14-2	Invert	Yes[U]	Yes	Yes	?	Sample results not in pit report (WOGCC 2015) nor posted online.	~50	1,000	?	Sample results not in pit report (WOGCC 2015) nor posted online.	Qa	PGDW05 (64m,299m,SE) PGDW45 (31m,272m,SE) PGDW40 (67m,357m,NW)	Yes	VRP	VRP	Well completion in 1981. On 1/18/1981, "operator noticed large gas flow from SI well…flow was from partially opened valve on 8 5/8 x 5 ½ in annulus…laid line to pit + started flowing to pit…Circ 180 bbls…gel salt water…in annulus…circ fluid to pit…top of cmt very poor." Acid stimulation in 1981 using HCl and KCl solutions. On 3/11/1981, "well flowing to pit…approx. 500 bbls wtr." On 3/26/1981 "reversed acid to pit." Hydraulic fracturing in 1981 using "YF4PSD, gelled water, J-347 gelling agent, J-218 breaker, J-218 breaker, J-318 breaker aid" and other additives. "Swabbed to pit" On 4/6/1981. "Well producing approx. 75 bbls wtr per day…well died to wtr build up." On 2/23/1983, surface damages paid for "inverted mud blow out" on 1/18/1981 and "condensate blow out" in Oct 1982. No produced water documented until 2005. Sundry notice for offsite disposal of production fluids in Jan 1998. Pit was reinstated into the VRP program in July 2014. Soil borings and groundwater monitoring wells installed in October 2014. Encana is drafting a report recommending site closure.
1-8-1B	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Twdr	None	No	NI	No	Well completion and P&A in 1981. Well completion report not available. Stimulation or production unlikely.
21-9	Invert	Yes[U]	Yes	Yes	47	GRO: 700 (n=67) DRO: 39,000 (n=67) Benzene: ND (n=49) Toluene: 0.094 (n=47) Ethylbenzene: 2.4 (n=47) Xylenes: 20 (n=47)	~8,522	1,000	4	GRO: ND (n=4) DRO: 880 (n=4) BTEX: ND (n=4)	Qa	PGDW42 (61m,237m,SE)		Yes	No	Well completion in 1981. Acid stimulation in 1981. Hydraulic fracturing in 1981 using "gelled water." P&A in 1992. 11 bbls produced water in 1986. No description of where flowback and production fluids were disposed.
12-3	Invert	Yes[U]	Yes	Yes	5	TPH: 161 (n=5)	0	5,000	0	Not sampled	Qa	P66345.0W (21m,327m,S) PGDW41 (21m,524m,SW)	No	?	?	Acid stimulation in 1981. No description of where flowback and production fluids were disposed. Sundry notice for offsite disposal of production fluids in Jan 1998. No produced water until 2005 after which 1,270 bbls produced. Incorrect site photo and borehole logs in investigative report. Recommendation for additional investigation will be based upon file review.
RH 1	Invert	Yes[U]	No	No	0	Not sampled	0		0	Not sampled	Qa	PGDW03 (137m,382m,SE) PGDW04 (134m,521m,SE) P120203.0W (137m,377m,S) P23056.0P (116m,377m,S)	No	NI	Yes	Well completion and P&A in 1981. Well completion report not available. Stimulation or production unlikely.
1-4	Invert	Yes[U]	Yes	Yes	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Acid stimulation and hydraulic fracturing during well completion in 1982. No description of where flowback and production fluids were disposed. Also, 2,867 bbls produced water by Jan 1993 and 4,124 bbls produced water by Jan 1998. No description of where produced water was disposed.
14-24	KCl Polymer	Yes[U]	Yes	Yes	0	Not sampled	0		0	Not sampled	Twdr	None755m,SW)	No	NI	No	Well completion and P&A in 1982. Acid stimulation in 1982. No description of where flowback and production fluids were disposed.

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A-1	Invert	Yes[U]	Yes	Yes	0	Not sampled	0		0	Not sampled	?	None	No	NI	No	Well completed in 1983. Acid stimulation and hydraulic fracturing in 1983. No description of where flowback and production fluids were disposed. Also, 7,072 bbls produced water from 1991 to 1995. No description of where produced water was disposed.
1-15	Invert	Yes[U]	Yes	Yes	0	Not sampled	0		0	Not sampled	Qa	None	No	NI	No	Well completion 1983. Acid stimulation and hydraulic fracturing with KCl solution and "gel water" in Cody Formation in 1983. P&A in 1990. 19 bbls produced water in 1983. No description of where flowback, produced water, and other production fluids were disposed
B-1	Invert	Yes[U]	Yes	Yes	0	Not sampled	0		0	Not sampled	?	None	No	NI	No	Well completion and P&A in 1984. Acid stimulation in 1984 with HCl and HF solutions. Hydraulic fracturing in 1984 with undiluted diesel fuel. No description of where flowback was disposed.
33-11	KCl polymer	Yes[L]	No	Yes	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	No	NI	No	Well completion in 1993. Drilling mud samples up 27,000 mg/l Cl. Acid stimulation in 1993. Hydraulic fracturing in 1993 using CO_2 foam. 1,442 bbls produced water by Jan 1998. No description of where flowback, produced water, and other potential production fluids were disposed. Sundry notice for offsite disposal of production fluids in Jan 1998. Encana states that cuttings were buried at offsite location north of a rock out crop near Tribal Pavillion 42X-11. A nearby monitoring well 5 showed no indication of contamination.
12-11	KCl polymer	Yes[L]	No	Yes	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	Yes	NI	No	Well completion in 1993. Drilling mud up to 22,000 mg/l Cl. Hydraulic fracturing with CO_2 foam and KCl solution in 1993. No description of where flowback was disposed. No produced water until recompletion in 2004. Sundry notice for offsite disposal of production fluids in Jan 1998. Investigation recommended by WOGCC at one pit containing KCl polymer.
11-10	KCl polymer	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	No	NI	No	Well completion in 1993. No apparent stimulation prior to recompletion in 2004. 5,508 bbl produced water from Jan 1994 – Jan 1998. No description of where produced water was disposed. Sundry notice for offsite disposal of production fluids in Jan 1998. Encana states that although a concrete pad is at this location, there is no documentation that it was used. .
42-10	KCl polymer	Yes[L]	No	Yes	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	Yes	NI	No	Well completion in 1994. Acid stimulation in 1994. 3,025 bbl produced water from Jan 1994 – Jan 1998. No description of where flowback and produced water were disposed. Sundry notice for offsite disposal of production fluids in Jan 1998. Investigation recommended by WOGCC at one pit containing KCl polymer.
31-10	KCl polymer	Yes[C]	No	Yes	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	Yes	NI	No	Well completion in 1994. Acid stimulation in 1994. 3,850 bbls produced water from Jan 1994 – Jan 1998. No description of where flowback and produced water were disposed. Sundry notice for offsite disposal of production fluids in Jan 1998.

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23-10	KCl polymer	Yes[L]	No	Yes	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	Yes	NI	No	Well completion in 1994. Acid stimulation and hydraulic fracturing with N_2 foam in 1994. No description of where flowback was disposed. 23,700 bbls produced water from Jan 1994 – Jan 1998. Sundry notice dated 4/27/1995 requesting approval to store produced water in a 210 bbl steel tank for offsite disposal. Sundry notice for offsite disposal of prod fluids in Jan 1998. Investigation recommended by WOGCC at one pit containing KCl polymer
43-10	KCl polymer	Yes[L]	No	Yes	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	Yes	NI	No	Well completion in 1994. Mud pit sample 9,500 mg/l Cl. Acid stimulation and hydraulic fracturing using N_2 foam in 1994. 85 bbls produced water in 1995. No description of where flowback and produced water were disposed. Sundry notice for offsite disposal of production fluids in Jan 1998. Part of cuttings pit exposed due to movement of landowner road.
33-2	KCl polymer	Yes[C]	No	Yes	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	No	NI	No	Acid stimulation in 1994. 269 bbl produced water Jan 1994 – Jan 1998. No description of where flowback and produced water was disposed. Sundry notice for offsite disposal of production fluids in Jan 1998.
23-1	KCl polymer	Yes[L]	No	Yes	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	No	NI	No	Mud pit sample 36,360 mg/l Cl. Acid stimulation in 1994. 200 bbl produced water from Jan 1994–Jan 1998. Sundry notice dated 4/27/1995 to store produced water in 70 bbl steel tank for offsite disposal. Sundry notice for offsite disposal of production fluids in Jan 1998 – unclear how production fluids were disposed of prior to this date. Investigation recommended by WOGCC at one pit containing KCl polymer
41-15	KCl Polymer	Yes[C]	No	Yes	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	No	NI	No	Mud pit sample 35,150 mg/l Cl. Acid stimulation and hydraulic fracturing using N_2 foam in 1994. "Let well open to test tank" Sundry notice for offsite disposal of production fluids in Jan 1998 – unclear how production fluids were disposed of prior to this date. Completion record not reviewed by WOGCC (2014).
43-6	KCl Polymer	?	No	Yes	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	No	NI	No	Acid stimulation in 1995. No produced water until 2008. Sundry notice for offsite disposal of production fluids in Jan 1998 – unclear how production fluids were disposed of prior to this date.
23-11	KCl polymer	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
31-11X	KCl polymer	?	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	NI	No	No well site disposal of production fluids.
13X-3	PHPA/LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
42X-9	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	NA	NI	No	No well site disposal of production fluids.
41-11	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
33-10	PHPA/LSND	?	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	NI	No	No well site disposal of production fluids.
33-3	PHPA	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	NA	NI	No	No well site disposal of production fluids.
44-3	PHPA/LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	NA	NI	No	No well site disposal of production fluids.
15-21X	Invert	?	No	No	0	Not sampled	0		0	Not sampled	Qa	Not evaluated	NA	NI	No	No well site disposal of production fluids. Disposal of "solidified" invert mud and cuttings unknown. Encana states that cuttings were "solidified"
32-10	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	NA	NI	No	No well site disposal of production fluids.
13-11	PHPA	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	NI	No	No well site disposal of production fluids.
21-13	DeepDrill®	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	NI	No	No well site disposal of production fluids.
43-2	Unknown[R]	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	NI	No	No well site disposal of production fluids.
13-2	DeepDrill®	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	NI	No	No well site disposal of production fluids.
24-1	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
32-1	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	NI	No	No well site disposal of production fluids.
34-2	LSND	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	NI	No	No well site disposal of production fluids.
12-6	DeepDrill	?	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	NI	No	No well site disposal of production fluids.
44-1	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	NI	No	No well site disposal of production fluids.
14-10	DeepDrill®	?	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	NI	No	No well site disposal of production fluids.

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13-15	PHPA	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
12-11W	LSND	?	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	?	No	No well site disposal of production fluids.
34-3R	PHPA	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
11-11	PHPA	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
12-5	PHPA	?	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	?	No	No well site disposal of production fluids.
13-12	LSND	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
34-11	"gel"	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
13-1	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	?	No	No well site disposal of production fluids.
11-12	LSND	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
21-10	LSND	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
43-1	PHPA	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	?	No	No well site disposal of production fluids.
33-1	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	?	No	No well site disposal of production fluids.
12-7	LSND	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
21-10W	LSND	No[D]	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
23-12	LSND	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
44-2	?	?	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	?	No	No well site disposal of production fluids.
31-9	LSND	Yes[L]	No	No	3	GRO: ND (0.5) (n=3) DRO: ND (4) (n=3) SVOC: ND (n=1)	0	1,000	0	Not sampled	Qa	Not evaluated	NA	?	No	No well site disposal of production fluids.
34-10	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	PGDW11 (107m,436m SE)	NA	?	No	Lozier pit disposal area. No well site disposal of production fluid.
34-1	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	NA	?	No	No well site disposal of production fluids.
21-12	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	NA	?	No	No well site disposal of production fluids.
12-10	LSND	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	Not evaluated	NA	Yes[C]	No	No well site disposal of production fluids.
12-1	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	?	No	No well site disposal of production fluids.
42-3	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	NA	?	No	No well site disposal of production fluids.
22-1	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	?	No	No well site disposal of production fluids.
33-10W	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
41-3	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa		NA	?	No	No well site disposal of production fluids.
22-11	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
43-11	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
11-3	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
41-10	LSND	No[D]	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
13-12W	PHPA	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
24-3B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
11-11B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
31-11	LSND	Yes[C]	No	No	0	Multiple locations[W]	0		0	Not sampled	?	?	NA	Yes[C]	No	No well site disposal of production fluids.
23-3	?	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
32-11	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
44-11	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
42-9W	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
32-9W	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
32-10B	LSND	No[D]	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
13-11B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
14-03W	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
12-2	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	Not evaluated	NA	?	No	No well site disposal of production fluids.
23-10W	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	?	No	No well site disposal of production fluids.
23-10C	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	?	No	No well site disposal of production fluids.
34-3B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
24-2	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
23-10B	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	?	No	No well site disposal of production fluids.
33-10B	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr	Not evaluated	NA	?	No	No well site disposal of production fluids.
12-11B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
43-10B	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa		NA	?	No	No well site disposal of production fluids.
24-11	LSND	No[D]	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
31-10B	LSND	No[D]	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
33-11B	"water based"	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA

Production Well Abbreviation	Drilling Mud Used Below Surface Casing	Pit Used or Likely Used to Dispose Drilling Mud and Cuttings Onsite	Pit Used or Likely Used for Disposal of Production Fluids?	Stimulated Prior to Jan 1995?	Number of Soil Screening Locations	Maximum Soil Contamination (mg/kg) and Number of Soil Samples	Excavation Volume (yd³)	Excavation Criterion (mg/kg TPH)	Number of Ground-Water Sampling Locations	Maximum Ground-Water Contamination in Surficial Deposits (µg/l) and Number of Ground-Water Samples	Surficial Geology	Domestic Wells Within 600 m of Production Wells (Depth, Distance, Direction from Production well)	Stimulation Record Reviewed by WOGCC (2014)	Adequate Site Assessment as Judged by WOGCC (2015)	Further Investigation Recommended by WOGCC (2015)	Comments
44-11B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
21-14	LSND	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa		NA	NI	No	No well site disposal of production fluids.
13-10	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
21-10B	"water based"	No[D]	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
43-11B	"water based"	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
42-10B	LSND	No[D]	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
22-11B	"water mud"	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
32-10C	LSND	No[D]	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
22-11C	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
44-4	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
12-12	"water based"	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
33-2C	LSND/PHPA	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
13-2B	?	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
43-4	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
33-2B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
14-3B	DeepDrill®	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
41-11B	?	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
42-4B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
21-11B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
13-3W	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
41-10B	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
34-28	DeepDrill®	?	No	No	0	Multiple locations[W]	0		0	Not sampled	?		NA	NI	No	No well site disposal of production fluids.
32-3	LSND	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
43-9	DeepDrill®	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
22-3	"water based"	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
44-3C	?	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
32-2	"Gel-Chem"	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
33-12	"Gel-Chem"	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
14-21	KCL Polymer	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Twdr		NA	NI	No	Well completion in 2006. No well site disposal of production fluids. Investigation recommended by WOGCC at one pit containing KCl polymer
22-4	PHPA	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA
42-15	PHPA	Yes[L]	No	No	0	Multiple locations[W]	0		0	Not sampled	Qa	?	NA		No	No well site disposal of production fluids.
41-26	Water based	No	No	NA	NA	NA	NA		NA	NA	NA	NA	NA	NA	NA	NA

Abbreviations
? – Unknown
VRP – Voluntary Remediation Program
PHPA - partially hydrolized polyacrylamides
LSND - low solids non-dispersed drilling mud
DeepDrill® is a product of Newpark Drilling Fluids and is described as a buffered blend of polyhydroxyl alcohols. No MSDS on this product was provided to EPA
ND – non detect (reporting limit in report)
NI – not investigated
Qa - Quaternary Deposits
Twdr – Wind River Formation
n – number of samples
NA – not applicable

Superscripts
D - Cuttings disposed at pit near 34-10
C - Cuttings used for tank berms/tank battery or spread on surface at location
L – Pits lined after 1993.
U – Pits unlined prior to 1993.
W – Cuttings for water-based mud sampled by Encana at 40 production wells between 2001 and 2006. All samples analyzed for TPH with highest TPH value of 645 mg/kg. Two samples were analyzed for chloride (115 and 215 mg/kg). Data set not available.

Table SI F3. Summary of detection of light hydrocarbons and organic compounds in domestic wells less than and greater than 600 m from unlined pits. Concentrations in μg/L unless otherwise indicated.

Well Name	Date	Methane	Ethane	Propane	GRO	DRO	DRO (SGCU)	Adamantane	1,3-Dimethyl Adamantane	Other Hydrocarbons and TICs	References
Domestic Wells < 600 m from unlined pits potentially receiving production fluids											
PGDW05	Mar-09	16.6	NA	NA	NA	105	NA	NA	NA		EPA[29]
	Jan-10	5.44(J)	<10.0	<15.0	26.3/31.1	75.3/76.4	NA	<0.20(J)/<0.20(J)	1.74(J)/1.71(J)	2-methyladamantane (TIC) - 2.5 μg/L	EPA[30]
	Apr-11	90(B)	66(B)	<6.7	42.8(B)	68.1(B)	NA	0.12(J)	1.35(J)	1,3-dimethyladamantane + isomers (TIC) – 8.6 μg/L	EPA[27]
	Apr-12	53(B)	<0.27	<3.8	48	63.5	NA	<0.25	2.82	2-methyladamantane (TIC) – 3.39 μg/L cis-1,4-dimethyladamantane (TIC) – 1.37 μg/L	EPA[33]
	Jun-14	33	ND	ND	ND	ND	26(J)	NA	NA	isopropanol – 8.1(J) μg/L	WYDEQ[34]
	Aug-14	72	ND	ND	ND	93(J)	31(J)	NA	NA		WYDEQ[34]
PGDW06	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW11	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW14	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
	Apr-11	23(B)	<4.8	<6.7	<20.0	<20.8	NA	<0.10	<0.10		EPA[27]
	Jun-14	0.54(J)	ND	ND	ND	29(J)	ND	NA	NA	isopropanol – 6.0(J) μg/L naphthalene – 0.6(J) μg/L	WYDEQ[34]
	Aug-14	0.2(J)	ND	ND	ND	ND	ND	NA	NA		WYDEQ[34]
PGDW20	Mar-09	137	NA	NA	<20	17.3	NA	NA	NA		EPA[29]
	Jan-10	172	10.9	<15.0	<20.0	21.7	NA	<0.20(J)	<0.20(J)	2-methyladamantane (TIC) - 0.49 μg/L	EPA[30]
	Oct-10	190(B)	20(B)	<4.1	<20.0/<20.0	<22.0	NA	1.35(J)/1.37(J)	0.14(J)/0.14(J)	2-methyladamantane (TIC) – 1.03/0.43 μg/L	EPA[27]
	Apr-11	137(B)	80(B)	<6.7	<20.0	<21.9	NA	<0.10	<0.10	1-isobutyladamantane (TIC) – 0.27 μg/L	EPA[27]
	Apr-12	111/108	8.0/7.0	<3.8/<3.8	<20.0/<20.0	<20.0/<20.0	NA	<0.25	<0.25/<0.25	2-methyladamantane (TIC) – 0.67 μg/L	EPA[33]
	Jun-14	110	7	0.59(J)	ND	ND	ND	NA	NA	acetone – 1.8(J) μg/L	WYDEQ[34]
	Aug-14	130	8	0.24(J)	ND	43(J)	ND	NA	NA		WYDEQ[34]
PGDW20 (carbon trap)	Mar-09	NA	NA	NA	NA	377	NA	NA	NA		EPA[29]
PGDW20 (RO filter)	Jan-10	NA	NA	NA	NA	752,000 μg/kg	NA	420 μg/kg	2960 μg/kg	2-methyladamantane (TIC) – 9400 μg/kg	EPA[30]
LD-02	Oct-10	230(B)	20(B)	<4.1	<20.0	111	NA	0.510(J)	<0.25(J)	benzene – 0.060(J) μg/L ethylbenzene – 0.240(J) μg/L o-xylene – 0.260(J) μg/L 1,2,4-trimethylbenzene – 0.200(J) μg/L 1,3,5-trimethylbenzene – 0.210(J) μg/L isopropylbenzene – 0.350(J) μg/L methyl *tert*-butyl ether – 0.140(J) μg/L	EPA[27]
	Jun-14	18	0.2(J)	ND	ND	ND	ND	NA	NA		WYDEQ[34]
	Aug-14	12	0.43(J)	ND	ND	77(J)	ND	NA	NA	pyruvic Acid – 2060 μg/L	WYDEQ[34]
PGDW21	Mar-09	54.1	NA	NA	NA	NA	NA	NA	NA		EPA[27]
PGDW22	Mar-09	<5.00	NA	NA	<20	27.1	NA	<0.20(J)	<0.20(J)		EPA[29]
	Jan-10	<5.00	<10.0	<15.0	<20	154	NA	<0.10	<0.10		EPA[30]
PGDW23	Mar-09	146	NA	NA	<20	<15.0	NA	NA	NA		EPA[29]
	Jan-10	149	<10.0	<15.0	<20	<20.0	NA	<0.20(J)	<0.20(J)		EPA[30]
	Apr-11	178(B)	<4.8	<6.7	<20.0	21.1(B)	NA	<0.10	<0.10		EPA[27]

Well Name	Date	Methane	Ethane	Propane	GRO	DRO	DRO (SGCU)	Adamantane	1,3-Dimethyl Adamantane	Other Hydrocarbons and TICs	References
	Apr-12	226	19	11.4	<20.0	<20.0	NA	<0.25	<0.25		EPA[33]
	Jun-14	98	0.76(J)	ND	ND	21(J)	ND	NA	NA	beta-BHC – 0.06 (J) µg/L	WYDEQ[34]
	Aug-14	210	0.77(J)	ND	ND	ND	ND	NA	NA		WYDEQ[34]
PGDW26	Mar-09	<5.00	NA	NA	NA	NA	NA	NA	NA		EPA[29]
	Apr-11	27(B)	<4.8	<6.7	<20.0	47.2	NA	<0.10	<0.10		EPA[27]
PGDW30	Mar-09	558	NA	NA	NA	46.8	NA	NA	NA		EPA[29]
	Jan-10	808	<10.0	<15.0	<20.0	35.0	NA	<0.20(J)	1.81(J)	1,3,5-trimethyladamantane (TIC) - 0.29 ug/L	EPA[30]
	Oct-10	760(B)	<3.0	<4.1	29.4	32.7	NA	<0.25	2.48		EPA[27]
	Apr-11	644	76(B)	<6.7	21.6(B)	37.0	NA	<0.10	0.98	1,3-dimethyladamantane + isomers (TIC) - 3.96 µg/L	EPA[27]
	Apr-12	384	3	<3.8	27.3	43.8	NA	<0.25	2.50	1,4-dimethyladamantane (TIC) – 2.33 µg/L	EPA[33]
	Jun-14	720	0.39(J)	ND	ND	34(J)	21(J)	NA	NA		WYDEQ[34]
	Aug-14	1100	0.61(J)	ND	ND	74(J)	ND	NA	NA		WYDEQ[34]
PGDW32	Mar-09	21.4	NA	NA	NA	19.2	NA	NA	NA		EPA[29]
	Jan-10	36.3	<10.0	<15.0	22.6	<20.0	NA	0.30	<0.20	1-ethyl-4-methyl benzene (TIC) - 0.17 ug/L	EPA[29]
	Apr-11	67(B)	<4.8	<6.7	22.4(B)	<20.9/<22	NA	0.12(J)/0.12(J)	<0.10/<0.10		EPA[27]
	Jun-14	33	0.2 (J)	0.2(J)	ND	ND	ND	NA	NA	isopropanol – 24 (J) µg/L isopropylbenzene – 0.1(J) µg/L *tert*-butyl alcohol – 2.0(J) µg/L gamma BHC (lindane) – 0.08(J) µg/L	WYDEQ[34]
	Aug-14	68	ND	ND	ND	ND	ND	NA	NA	isopropylbenzene – 0.1(J) µg/L	WYDEQ[34]
PGDW33	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
	Jun-14	0.44(J)	ND	ND	ND	ND	ND	NA	NA	2-butoxyethanol – 3300(J) µg/L isopropanol – 3.5(J) µg/L endosulfan II – 0.1(J) µg/L gamma BHC (lindane) – 0.1(J) µg/L	WYDEQ[34]
	Aug-14	0.3(J)	ND	ND	ND	ND	ND	NA	NA		WYDEQ[34]
PGDW34	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW35	Mar-09	21.6	NA	NA	NA	17.9	NA	NA	NA		EPA[29]
PGDW36	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW40	Jan-10	98.9	<10.0	<15.0	<20.0	32.6	NA	<0.20	0.36		EPA[30]
PGDW41A	Jun-14	ND	ND	ND	ND	150(J)	ND	NA	NA	methylene chloride – 0.2(J) µg/L	WYDEQ[34]
PGDW41	Jan-10	<5.00	<10.0	<15.0	<20.0	479	NA	<0.20	<0.20		EPA[30]
	Apr-11	385	142(B)	<6.7	<20.0	132	NA	<0.25	<0.25		EPA[27]
	Jun-14	1.6(J)	0.2(J)	ND	ND	170(J)	180(J)	NA	NA		WYDEQ[34]
	Aug-14	2.0(J)	ND	ND	ND	250(J)	230(J)	NA	NA		WYDEQ[34]
PGDW42	Jan-10	60.0	<10.0	<15.0	<20.0	21.6	NA	<0.20(J)	<0.20(J)		EPA[30]
PGDW43	Jan-10	<5.00	<10.0	<15.0	<20.0	49.7	NA	<0.20	<0.20	benzene – 0.540 µg/L acenaphthylene – 0.210 µg/L naphthalene – 0.300 µg/L phenol – 0.170 µg/L	EPA[30]
PGDW44	Jan-10	<5.00	<10.0	<15.0	<20.0	44.3	NA	<0.20(J)	<0.20(J)	2-methylnaphthalene - 0.370(J) µg/L fluorene - 0.150(J) µg/L 1-methyl naphthalene (TIC) - 0.33 µg/L 1,6-dimethyl naphthalene (TIC) - 0.42 µg/L 1,7-dimethyl naphthalene (TIC) - 0.48 µg/L 2,7-dimethyl naphthalene (TIC) - 0.25 µg/L	EPA[30]

Well Name	Date	Methane	Ethane	Propane	GRO	DRO	DRO (SGCU)	Adamantane	1,3-Dimethyl Adamantane	Other Hydrocarbons and TICs	References
	Apr-11	24(B)	<4.8	<6.7	<20.0	60.5(B)	NA	<0.25	<0.25		EPA[27]
	Jun-14	1.3(JP)	0.37(J)	0.51(J)	ND	31(J)	ND	NA	NA	isopropanol – 11(J) gamma BHC (lindane) – 0.02(J) naphthalene – 0.2(J)	WYDEQ[34]
	Aug-14	1.4(J)	0.43(J)	0.59(J)				NA	NA		WYDEQ[34]
PGDW45	Jan-10	<5.00	<10.0	<15.0	<20.0	41.3	NA	<0.20(J)	<0.20(J)	1,3-dimethyladamantane + isomers – 9.5 µg/L	EPA[30]
	Apr-11	24(B)	64(B)	<6.7	<20.0	32.1	NA	<0.10	1.25		EPA[27]
	Jun-14	1(J)	ND	ND	25(J)	ND	33(J)	NA	NA	isopropanol – 15(J) µg/L gamma BHC (lindane) - 0.06(J) µg/L	WYDEQ[34]
PGDW46	Jan-10	<5.00	<10.0	<15.0	<20.0	25.5	NA	<0.20	<0.20		EPA[30]
PGDW47	Jan-10	<5.00	<10.0	<15.0	<20.0	26.6	NA	<0.20(J)	<0.20(J)		EPA[30]
PGDW48	Jan-10	<5.00	<10.0	<15.0	<20.0	<20.0	NA	<0.20	<0.20		EPA[30]
PGDW49	Jan-10	<5.00	<10.0	<15.0	<20.0	130	NA	<0.20	<0.20		EPA[30]
	Apr-11	24(B)	62(B)	<6.7	<20.0	51.9	NA	<0.10	<0.10		EPA[27]
	Jun-14	0.2(JP)	ND	ND	ND	110(J)	ND	NA	NA	endosufan II – 0.07(J) µg/L	WYDEQ[34]
	Aug-14	0.3(JP)	ND	ND	ND	38(J)	ND	NA	NA		WYDEQ[34]
P108128.0W	NS										
P124049.0W	NS										
P146856.0W	NS										
P197335.0W	NS										
P197336.0W	NS										
P200885.0W	NS										
P22660.0P	NS										
P22661.0P	NS										
P22662.0P	NS										
P24502.0P	NS										
P24508.0P	NS										
P29496.0P	NS										
P31805.0W	NS										
P41320.0W	NS										
P41517.0W	NS										
P44255.0W	NS										
P59499.0W	NS										
P60032.0W	NS										
P66345.0W	NS										
P69549.0W	NS										
P91293.0W	NS										
P99671.0W	NS										
Domestic Wells < 600 m from Unlined Pits Not Receiving Production Fluids											
PGDW03	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
	Jan-10	<5.00	<10.0	<15.0	<20.0	<20.0	NA	<0.20	<0.20		EPA[30]
PGDW04	Mar-09	<5.00	NA	NA	<20.0	<15.0	NA	NA	NA		EPA[29]
	Jan-10	<5.00	<10.0	<15.0	<20.0	<20.0	NA	<0.20	<.020		EPA[30]
PGDW13	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW15	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
P120203.0W	NS										
P23056.0P	NS										

Well Name	Date	Methane	Ethane	Propane	GRO	DRO	DRO (SGCU)	Adamantane	1,3-Dimethyl Adamantane	Other Hydrocarbons and TICs	References
P65111.0W	NS										
P95171.0W	NS										
P9334.0P	NS										
P9441.0P	NS										
CR UW09/250	NS										
Domestic Wells > 600m From an Unlined Pits											
PGPW01	Mar-09	<5.00	NA	NA	NA	17.1	NA	NA	NA		EPA[29]
	Jan-10	NA	NA	NA	NA	<20.0	NA	<0.20	<0.20		EPA[30]
PGPW02	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
	Jan-10	NA	NA	NA	NA	<20.0	NA	<0.20	<0.20		EPA[30]
	Apr-12	8(B)	<2.7	<3.8	<20.0	<20.0	NA	<0.25	<0.25		EPA[33]
PGDW01	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW02	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW09	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW10	Mar-09	<5.00	NA	NA	<20	23.1	NA	<0.20(J)	<0.20(J)		EPA[29]
	Jan-10	<5.00(J)	<10.0(J)	<15.0(J)	<20	<20.0	NA	<0.25	<0.25		EPA[30]
PGDW12	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW16	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW17	Mar-09	10.6	NA	NA	NA	17.5	NA	NA	NA		EPA[29]
PGDW18	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW19	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW24	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW25	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
	Jan-10	<5.00	<10.0	<15.0	<20	27.8	NA	<0.20	<0.20		EPA[30]
PGDW28	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW29	Mar-09	<5.00	NA	NA	NA	16.2	NA	NA	NA		EPA[29]
PGDW31	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW37	Mar-09	NA	NA	NA	NA	NA	NA	NA	NA		EPA[29]
PGDW38	Mar-09	<5.00	NA	NA	NA	19.7	NA	NA	NA		EPA[29]
PGDW39	Jan-10	<5.00	<10.0	<15.0	<20.0	30.0	NA	<0.20(J)	<0.20(J)		EPA[30]
PGDW50	Apr-12	<1.3	<2.7	<3.8	<20.0	<20.0	NA	<0.25	<0.25		EPA[33]

Data (tables) from WYDEQ obtained from the Powder River Basin Resource Council in April 2015.
NS – Not sampled
NA – Not analyzed
ND – Not detected. Method detection and reporting limits not known
TICs – Tentatively identified compounds
J – Estimated value
B – Compound detection in blank. For EPA data, detection less than 10X value in blank.
SGCU – Silica gel cleanup performed before analysis

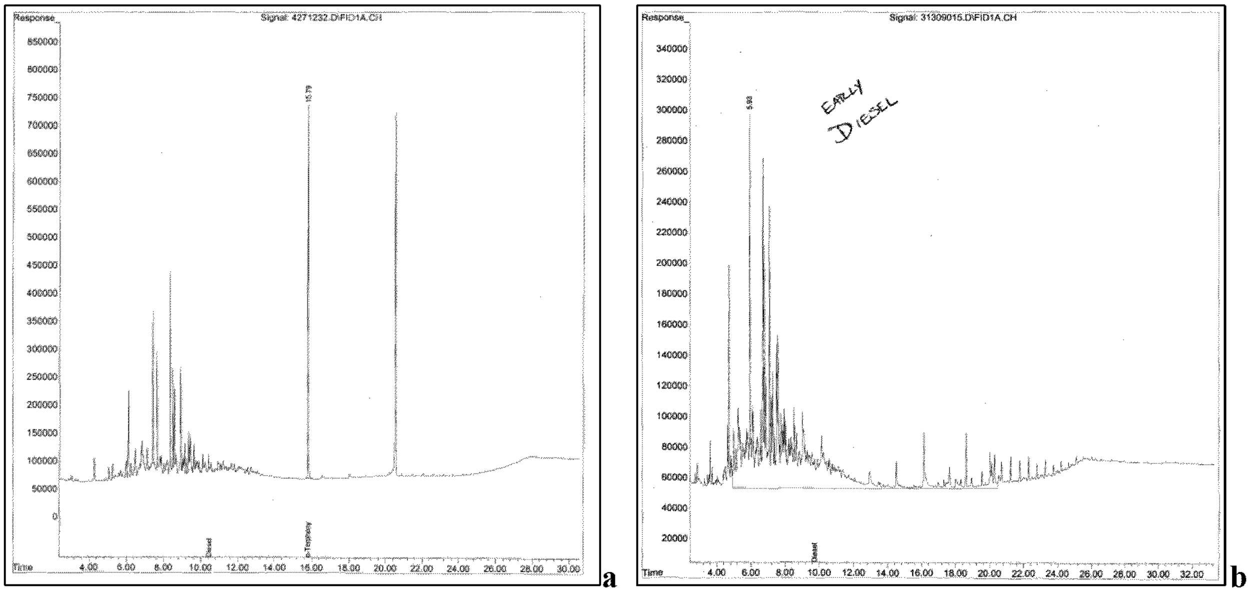

Figure SI F1. Chromatograms of DRO analysis at (a) PGDW05 during Phase V sampling event, and (b) PGDW30 during Phase I sampling event. Handwritten note, "Early Diesel", by EPA Region 8 chemist.

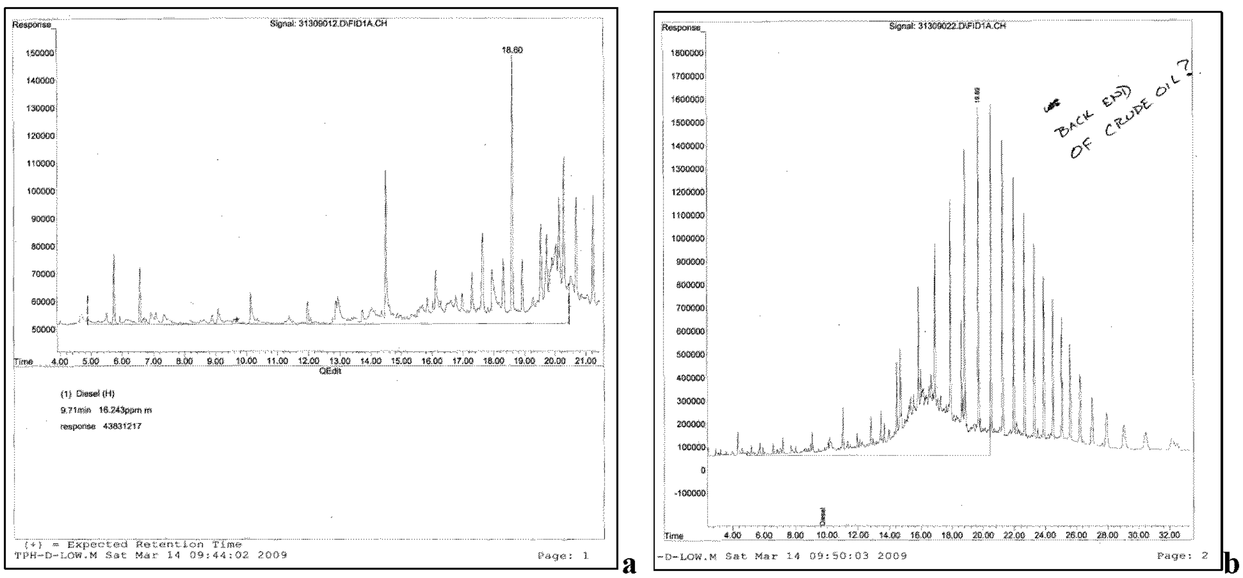

Figure SI F2. Chromatograms of DRO analysis at PGDW20 during Phase I sampling event (a) aqueous sample (b) carbon trap sample. Handwritten note, "Back End of Crude Oil" by EPA Region 8 analytical chemist. During the Phase (I) sampling event, water was circulated through a carbon trap for 24 hours (cumulative water approximately 2,950 L) with detection of DRO at 377 µg/L (EPA 2009).

G. Drilling Fluids Remaining in Wellbores

A review of well completion reports, drilling reports, and wireline geophysical logs indicates that invert mud consisted up to 79% oil (Unit 41X-10). At Govt 23-7, Q-BROXIN Gel, a ferrochrome lignosulfonate based gel[107] was used which contains high concentrations of chromium (e.g., > 16,000 mg/kg)[108]. After 1993, water-based mud systems consisted of KCl polymer, partially hydrolized polyacrylamides (PHPA), low solids non-dispersed drilling mud (LSND), and "DeepDrill" drilling systems (Table SI C1). MSDSs indicate that "*NewPHPA*" contained 24% hydrotreated light petroleum distillate.

The contact length of drilling mud to the Wind River and Fort Union Formations was estimated by the difference in depth to surface casing and depth to top of primary cement outside production casing based on available information from cement bond logs (CBLs) and temperature logs. Production casing was not used for 16 "dry" exploration wells (no cement below surface casing with exception of plugs for abandonment) 14 of which were drilled using invert mud. CBLs were unavailable at 42 of 165 (25%) of production wells. Top of cement could not be discerned at 5 wells due to high and erratic amplitude readings characteristic of free pipe. The extent of drilling mud below casing could be estimated at 128 of 181 (71%) total production wells and at 36 of 58 (62%) of production wells where invert mud was used (Table SI C1). The elevation of surface casing and top of cement are illustrated in Figure SI F1.

Boreholes retaining drilling mud outside production casing represent vertical "line" source terms for mass flux of contaminants into a surrounding formation. However, a more complicated geometry occurs when mud is lost to a formation. For example at Tribal 1-21, invert mud was lost to the Wind River Formation at two depths (9.5 and 12.7 m^3), with the latter "*likely lost to a fractured zone.*" At USA Tribal 258 22-10, 39.7 m^3 of invert mud was lost to the Fort Union Formation at two depths. Given the composition of invert mud, impact to ground water is expected but the distribution of impact would be expected to be a function of linear extent of mud below surface casing, surface area of exposure, dispersion, biodegradation, and distance (both vertical and lateral) from boreholes, and local hydraulic gradients. No monitoring wells exist in the immediate of boreholes, thus assessment of impact is not possible.

Ground water contamination from invert mud retained in boreholes would be expected to be primarily manifested by detection of elevated levels of diesel range organics (DRO). Fourteen domestic wells in the Pavillion Field were identified as having sufficient depth or proximity to production wells to be potentially impacted by invert mud retained in boreholes (Table SI G1). Twelve of these wells were sampled by EPA of which 9 were analyzed for DRO. Given distance to production well, depths of surface casing and domestic wells, expected direction of ground water flow (east), and detection of elevated DRO, LD-02 appears to have the highest probability of impact with detection of DRO at 111 μg/L. However, if DRO detection is due to an anthropogenic source term, differentiation from other source terms (unlined pits and stimulation) is not possible with currently available data.

Table SI G1. Domestic wells greater than intermediate depth and distance to nearest production well with invert mud

EPA/ WY SEO Well Identification	Depth of Domestic Well (m bgs)	Nearby Production Well with Invert Mud	Direction from Production Well to Domestic Well	Distance (m)	Depth of Surface Casing (m bgs)	Depth of Surface Casing - Domestic Well (m)	Depth to Top of Primary Cement or Base of Borehole (m bgs)	Length of Invert Mud Below Surface Casing (m)	DRO (μg/L) except PGFM20 and EPa Phase
PGDW03	137.2	44-17 RH 1	SE SE	427 382	183.8 185.9	46.6 48.7	None None	1108 1035	<20.0 (II)
PGDW04	134.1	44-17 RH 1	SE SE	565 521	183.8 185.9	49.7 51.8	None None	1108 1035	<15.0 (I), < 20.0 (II)
PGDW06	115.8	1-31	SE	341	125.3	9.5	Unknown	Unknown	NA
PGDW11	unknown	44-10 31-15	NE SW	388 230	184.4 205.7	Unknown Unknown	585 Unknown	585 Unknown	NA
PGDW12	115.8	1-31	NW	491	125.3	9.5	Unknown	Unknown	NA
PGDW20	140.2	22-12	SE	172	178.6	38.4	Unknown†	Unknown	17.3 (I), 21.7 (II), <20/<20 (III), <21.9 (IV), < 20/<20 (V)
PGDW20 (Carbon Trap)	140.2	22-12	SE	172	178.6	38.4	Unknown†	Unknown	377 (I)
PGFM20 (RO Filter sample from PGDW20)	140.2	22-12	SE	172	178.6	38.4	Unknown†	Unknown	752,000 (μg/kg) (II)
PGDW21/LD-02	185.9	22-12	SE	172	178.6	-7.3	Unknown†	Unknown	111 (III)
PGDW22	unknown	14-12	SW	261	190.1	Unknown	191	0.9	27.1 (I), 154 (II)
PGDW32	205.7	12-13	NE	173	175.6	-30.1	290	114	19.2 (I), <20.9/<22.0 (IV)
PGDW43	unknown	41-9	NW	176	184.1	Unknown	274	90	49.7 (II)
PGDW47	147.5	21-15	N	350	188.7	41.2	Unknown	Unknown	26.6 (II)
PGDW48	115.8	44-15	SW	329	189.9	74.1	198	8	<20.0J (II)
P108128.0W	115.5	44-15	W	115	189.9	74.4	198	8	NA
P124049.0W	147.5	21-15	N	384	188.7	41.2	Unknown	Unknown	NA

† Well schematic indicates drilling mud below surface casing.

H – Summary of Analytical Data Sources

Table SI H1. Major reports summarizing data and/or data quality

Agency	Report Title	Date	Source (accessed 9/1/2015)
EPA	Site Inspection – Analytical Results Report Pavillion Area Groundwater Investigation Site, Pavillion, Fremont County, Wyoming	Aug 2009	http://www2.epa.gov/sites/production/files/documents/Pavillion_GWInvestigationARRTextAndMaps.pdf
EPA	U.S. Environmental Protection Agency (EPA 2010a). Expanded Site Investigation – Analytical Results Report Pavillion Area Groundwater Investigation, Fremont County, Wyoming	Aug 2010	http://www2.epa.gov/sites/production/files/documents/PavillionAnalyticalResultsReport.pdf
EPA	Pavillion Quality Assurance Project Plans (5 revisions)	Feb 2010	ftp://ftp.epa.gov/r8/pavilliondocs/QA_Documents/QAPPs/
EPA	Audits of Data Quality (ADQ) October 2010 Sampling Event	Apr 2011	ftp://ftp.epa.gov/r8/pavilliondocs/QA_Documents/Audits_Of_Data_Quality_Lab_Results/Phase3/
EPA	Audits of Data Quality (ADQ) January 2010 Sampling Event	Aug 2011	ftp://ftp.epa.gov/r8/pavilliondocs/QA_Documents/Audits_Of_Data_Quality_Lab_Results/Phase2/ADQ-R8-PhaseII/
EPA	Audits of Data Quality (ADQ) March 2009 Sampling Event	Dec 2011	ftp://ftp.epa.gov/r8/pavilliondocs/QA_Documents/Audits_Of_Data_Quality_Lab_Results/Phase1/ADQ-R8-PhaseI/
EPA	Audits of Data Quality (ADQ) April 2011 Sampling Event	Aug 2011	ftp://ftp.epa.gov/r8/pavilliondocs/QA_Documents/Audits_Of_Data_Quality_Lab_Results/Phase4/
EPA	Investigation of Ground Water Contamination near Pavillion, WY	Dec 2011	http://www2.epa.gov/region8/draft-investigation-ground-water-contamination-near-pavillion-wyoming
EPA	Investigation of Ground Water Contamination near Pavillion, Wyoming Phase V Sampling Event Summary of Methods and Results	Sep 2012	ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Narrative.pdf
EPA	Groundwater Sampling Results at Locations near Pavillion, WY Pavillion Phase V (April 2012) Groundwater Quality Results and - Control (QC) Data	Sep 2012	ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf
USGS	Transmittal of Contract Laboratory Results and Evaluation of Laboratory-Specific Quality Control Measures, U.S. Environmental Protection Agency Monitoring Well MW02, Pavillion Wyoming 2012, Administrative Report Prepared for the U.S. Environmental Protection Agency. Director Approved August 30, 2012	Aug 2012	ftp://ftp.epa.gov/r8/pavilliondocs/phase5/USGS_MW02_AdministrativeReportSep2012.pdf
USGS	Sampling and Analysis Plan for the Characterization of Groundwater Quality in Two Monitoring Wells near Pavillion, WY	Sep 2012	http://pubs.usgs.gov/of/2012/1197/
USGS	Groundwater-Quality and Quality-Control Data for Two Monitoring Wells near Pavillion, Wyoming, April and May 2012	Sep 2012	http://pubs.usgs.gov/ds/718/
USGS	Analytical Report: Job Number: 280-28076-1 Job Description: EPA - Pavillion Fracking	Sep 2012	ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
EPA	Pavillion Gas Well Integrity Evaluation	Jul 23 2013	ftp://ftp.epa.gov/r8/pavilliondocs/OtherDocuments/WellAndFieldPitsEvaluationJuly2013/GasWellIntegrityEvaluation25July2013Final.pdf
EPA	Pavillion Oil & Gas Field Pits Evaluation	Jul 25 2013	ftp://ftp.epa.gov/r8/pavilliondocs/OtherDocuments/WellAndFieldPitsEvaluationJuly2013/25July2013PavillionPitsReport4pmFinal.pdf
WOGCC	Pavillion Field Well Integrity Review	Oct 2014	http://wogcc.state.wy.us/pavillionworkinggrp/PAVILLION_REPORT_1082014_Final_Report.pdf
WOGCC	Pavillion Field Pit Review	Jun 2015	http://wogcc.state.wy.us/pavillionworkinggrp/PAVILLION_REPORT_1082014_Final_Report.pdf
WDEQ	Pavillion, Wyoming Area Domestic Water Wells Draft Final Report and Palatability Study	Dec 2015	http://deq.wyoming.gov/wqd/pavillion-investigation/

Table SI H2. Summary of analytical methods used and sources of data and associated information on quality control and assurance.

Parameters	Phase	Media	Methods	Lab	Sources (links) of Analytical and Associated Information on Quality Assurance and Control) accessed 9/1/2015)
Major ions, alkalinity	I	W	EPA Methods 300.0 and 310.1	EPA R8	ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase1/R8_Lab/85621LSR_Report_Alkalinity_Anions_DRO.pdf
	II	W	EPA Methods 300.0 and 310.1.	EPA R8	http://www2.epa.gov/sites/production/files/documents/PavillionAnalyticalResultsReport.pdf (data summary only)
	III	W	RSKSOPs 276v3 and 214v5. EPA Methods SW-846 6500, 350.1, and 353.2	EPA Ada	ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/ORD_GP_Lab_Analysis_for_Phase_III/
	IV	W	RSKSOPs 276v3 and 214v5. EPA Methods SW-846 6500, 350.1, and 353.2	EPA Ada	ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/ORD_GP_Lab_TOC_DIC_Analysis_Phase_IV/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/ORD_GP_Lab_TOC_DIC_Analysis_Phase_IV/DICrawdata.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/ORD_GP_Lab_TOC_DIC_Analysis_Phase_IV/EPAGP256rev.1_SS%236030_6032_R.Wilkin_Pavillion_Groundwater.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/ORD_GP_Lab_TOC_DIC_Analysis_Phase_IV/NPDOC_rawdata.pdf
	V	W	RSKSOPs 276v3 and 214v5. EPA Methods SW-846 6500, 350.1, and 353.2	EPA Ada	ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
	V	W	EPA Methods 300.0, 310.1, 9056, 9060	USGS TA	http://pubs.usgs.gov/ds/718/ (data summary only) ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix11_J28076-1Std_Tal_L4_Package_MiniFinalReport3.pdf ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
Dissolved Metals	I	W	EPA Methods 6010B, 6020, 7470A	EPA K	http://www2.epa.gov/sites/production/files/documents/Pavillion_GWInvestigationARRTextAndMaps.pdf (data summary only)
	I	W	EPA Methods 6010B, 6020, 7470A	EPA L	http://www2.epa.gov/sites/production/files/documents/Pavillion_GWInvestigationARRTextAndMaps.pdf (data summary only)
	II	W	EPA Methods 6010B, 6020, 7470A	EPA A4	http://www2.epa.gov/sites/production/files/documents/PavillionAnalyticalResultsReport.pdf (data summary only)
	III	W	RSKSOP 213v4 and 257v2, or 332V0 and EPA Methods 200.7 and 6020.	EPA S	ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Metals_Analysis_Phase_III/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Metals_Analysis_Phase_III/Shaw_Metals_Analysis_Phase_III-ICP_Data/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Metals_Analysis_Phase_III/Shaw_Metals_Analysis_Phase_III-ICP_Data/ICP_Data_1_of_2_101110.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Metals_Analysis_Phase_III/Shaw_Metals_Analysis_Phase_III-ICP_Data/ICP_Data_2_of_2_101110.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Metals_Analysis_Phase_III/Shaw_Metals_Analysis_Phase_III-ICP_Data/Pavillion_ICP-MS_Data.pdf
	IV	W	RSKSOP 213v4 and 257v2, or 332V0 and EPA Methods 200.7 and 6020.	EPA S	ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Metals_Phase_IV/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Metals_Phase_IV/7ME743SF_ICP-MS_1of2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Metals_Phase_IV/7ME743SF_ICP-MS_2of2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Metals_Phase_IV/7ME743SF_ICP_051011_1of2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Metals_Phase_IV/7ME743SF_ICP_051011_2of2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Metals_Phase_IV/7ME743SF_ICP_051111_1of2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Metals_Phase_IV/7ME743SF_ICP_051111_2of2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Metals_Phase_IV/7ME743SF_ICP_051211.pdf
	V	W	RSKSOP 213v4 and 257v2, or 332V0 and EPA Methods 200.7 and 6020.	EPA S	ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
	V	W	EPA Methods 6010B, 6020, 7470A	EPA C	ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix10_J28076-1Std_Tal_L4_Package_MiniFinalReport2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix11_J28076-1Std_Tal_L4_Package_MiniFinalReport3.pdf
	V	W	EPA Methods 6010B, 6020, 7470A	USGS TA	http://pubs.usgs.gov/ds/718/ (data summary only) ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix10_J28076-1Std_Tal_L4_Package_MiniFinalReport2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix11_J28076-1Std_Tal_L4_Package_MiniFinalReport3.pdf ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
Fixed Gases, C1-C4	I	W	ORGM-004	EPA R8	ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase1/R8_Lab/85622Headspace8270.pdf
	II	W	ORGM-004	EPA R8	http://www2.epa.gov/sites/production/files/documents/PavillionAnalyticalResultsReport.pdf (data summary only)

	III	W	RSKSOP-194v4, RSKSOP-175v5	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Light_Hydrocarbon_and_Fixed_Gases_Phase_III-Calibration_Plots/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Light_Hydrocarbons_and_Fixed_Gases_Phase_III/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Light_Hydrocarbon_and_Fixed_Gases_Phase_III-Calibration_Plots/calibration_plots.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Light_Hydrocarbon_and_Fixed_Gases_Phase_III-Calibration_Plots/calibration_table_Micro_3000.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Light_Hydrocarbon_and_Fixed_Gases_Phase_III-Calibration_Plots/chromatograms_and_reports.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Light_Hydrocarbons_and_Fixed_Gases_Phase_III/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Light_Hydrocarbons_and_Fixed_Gases_Phase_III/RSKSOP-194_4_Initial_Calibration_for_Micro_3000.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Light_Hydrocarbons_and_Fixed_Gases_Phase_III/RSKSOP-194_4_high_Initial_Calibration_for_Micro_3000.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_Light_Hydrocarbons_and_Fixed_Gases_Phase_III/Refinery_Gas_Initial_Calibration_for_Micro_3000.pdf
	IV		RSKSOP-194v4, RSKSOP-175v5	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Light_Hydrocarbons_and_Fixed_Gases_Phase_IV/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Light_Hydrocarbons_and_Fixed_Gases_Phase_IV/7OA724SF_SS%236030_6032_Pavillion_GC.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Light_Hydrocarbons_and_Fixed_Gases_Phase_IV/7OA767SF_ss%236030_6032Pavillion_GC.pdf
	V		RSKSOP-194v4, RSKSOP-175v5	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
	V		RSKSOP-175	USGS TA		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
C1-C4 Isotopes	III	W,G	Gas stripping and IRMS – No EPA Method	EPA I		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/
	IV	W	Gas stripping and IRMS – No EPA Method	EPA I		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Isotech_Gas_Analysis_Phase_IV/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Isotech_Ground_Water_Analysis_Phase_IV/
	V	W	Gas stripping and IRMS – No EPA Method	EPA I		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
Water Isotopes	III	W	RSKSOP334v0	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_IRMS_Analysis_for_Phase_III/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_IRMS_Analysis_for_Phase_III/Raw_Data-1.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_IRMS_Analysis_for_Phase_III/Raw_Data-2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/Shaw_IRMS_Analysis_for_Phase_III/Raw_Data_Summary_Table.pdf
	IV	W	RSKSOP334v0	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_IRMS_Data_Phase_IV/RawData1.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_IRMS_Data_Phase_IV/RawData2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_IRMS_Data_Phase_IV/RawData3.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_IRMS_Data_Phase_IV/RawDataSummary.pdf
	V	W	RSKSOP334v0	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
VOCs	I	W	EPA Contract Laboratory Program - EPA Method 8260B	EPA L		http://www2.epa.gov/sites/production/files/documents/Pavillion_GWInvestigationARRTextAndMaps.pdf (data summary only)
	II	W	EPA Contract Laboratory Program - EPA Method 8260B	EPA A		http://www2.epa.gov/sites/production/files/documents/PavillionAnalyticalResultsReport.pdf (data summary only)
	II	W	ORGM-501r1.1, EPA Methods SW-846 5035 and 8260B	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/GCMS8260VolatilesW.O.1001003.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/Jan2010VOCAnalysis-0B04001.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/Jan2010VOCAnalysis-0B10001.pdf
	II	PW		EPA Z		
	III	W	ORGM-501r1.1, EPA Methods SW-846 5035 and 8260B	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/Oct2010VOCAnalysis-0J18003.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/SequenceNo0J18003.pdf
	IV	W	ORGM-501r1.1, EPA Methods SW-846 5035 and 8260B	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R8LabDocumentation_PhaseIV/Apr2011R8LabDataPkg_SR1104024Pavillion.pdf

						ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R8LabDocumentation_PhaseIV/Apr2011R8LabDataPkg_SequenceNo1D25001.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R8LabDocumentation_PhaseIV/Apr2011R8LabDataPkg_SequenceNo1D29001.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R8LabDocumentation_PhaseIV/April2011VOCAnalysis-1D29001.pdf
	IV	W	RSKSOP-259v1, EPA Methods SW-846 5021A and 8260	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/Report.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA724SFSS%236030Part1.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA724SFSS%236030Part2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA724SFSS%236030Part3.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA724SFSS%236030Part4.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA724SFSS%236030Part5.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA724SFSS%236030Part6.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA724SFSS%236032Part1.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA724SFSS%236032Part2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA724SFSS%236032Part3.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/CalibrationCurves.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/7OA767SF_SS%236030_and_6032_23993_Wilkin_Pavillion_Groundwater_queue.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/QCdata.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/SampleData.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/SampleList_BFB_Tunes_and_AirWaterCheck.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_VOCs_Phase_IV/TextBackup.pdf
	V	W	ORGM-501r1.1, EPA Methods SW-846 5035 and 8260B	EPA R8		
	V	W	RSKSOP-259v1, EPA Methods SW-846 5021A and 8260B	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
	V	W	EPA Methods 5030B and 8260B	USGS TA		http://pubs.usgs.gov/ds/718/ (data summary only) ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix6_280-28076-1_DataValidationReview.pdf ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
SVOCs	I	W	ORGM-515r1.1 and EPA Methods 3520 and 8270D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase1/R8_Lab/85622Headspace8270.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase1/R8_Lab/March2009SVOCAnalysis-9C23005.pdf
	II	W, S	ORGM-515r1.1 and EPA Methods 3520 and 8270D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/GCMS8270SemivolatilesW.O.1001002and1001003.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/Jan2010SVOCAnalysis-0C08003.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/Jan2010SVOCAnalysis-PavillionSpecificCompounds-0C04002.pdf
	II	PW	ORGM-515r1.1 and EPA Methods 3520 and 8270D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/Jan2010SVOCAnalysis-PavillionSpecificCompoundsFilterAndProductionWater-0B17001and0B26002.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/Jan2010SVOCAnalysisProductionWater-0B19002.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/Jan2010SVOCAnalysisFilter-0B19001.pdf
	III	W	ORGM-515r1.1 and EPA Methods 3520 and 8270D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/Oct2010SVOCAnalysis-0J25006.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/Oct2010SVOCAnalysis-PavillionSpecificCompounds-0J27001.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/SequenceNo0J25006.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/SequenceNo0J27001.pdf
	IV	W	ORGM-515r1.1 and EPA Methods 3520 and 8270D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R8LabDocumentation_PhaseIV/April2011Region8LabDataPackageSequenceNo1E18003.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R8LabDocumentation_PhaseIV/April2011SVOCAnalysis-1E05006.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R8LabDocumentation_PhaseIV/April2011SVOCAnalysis-1E12003.pdf

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						ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R8LabDocumentation_PhaseIV/April2011SVOCAnalysis-PavillionSpecificCompounds-1E18003.pdf
	V	W	ORGM-515r1.1 and EPA Methods 3520 and 8270D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
	V	W	EPA Methods 3520C and 8270C	USGS TA		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
DRO	I	W	ORGM-508r1.0, EPA Methods 8015B and 8015D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase1/R8_Lab/85621LSR_Report_Alkalinity_Anions_DRO.pdf
	II	W, S	ORGM-508r1.0, EPA Methods 8015B and 8015D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/DROW.O.1001002and1001003and1001005.pdf
	II	W	ORGM-508r1.0, EPA Methods 8015B and 8015D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/SequenceNo0J12001.pdf
	III	W	ORGM-508r1.0, EPA Methods 8015B and 8015D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/PavillionNo2_LSR1010-017.pdf
	IV	W	ORGM-508r1.0, EPA Methods 8015B and 8015D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R8LabDocumentation_PhaseIV/Apr2011R8LabDataPkg_SequenceNo1D26001.pdf
	V	W	ORGM-508r1.0, EPA Methods 8015B and 8015D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
	V	W	EPA Methods 3510C and 8015B	USGS TA		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
GRO/BTEX	I	W	ORGM-506r1.0, EPA Method: 8015D, CLP	EPA R8,	E	http://www2.epa.gov/sites/production/files/documents/Pavillion_GWInvestigationARRTextAndMaps.pdf (data summary only)
	II	W, S	ORGM-506r1.0, EPA Method: 8015D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase2/R8Lab/GROW.O.1001003and1001005.pdf
	III	W	ORGM-506r1.0, EPA Method: 8015D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/SequenceNo0J06001.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase3/R8LabDocumentation_PhaseIII/SequenceNo0J07001.pdf
	IV	W	ORGM-506r1.0, EPA Method 8015D	EPA R8		
	V	W	ORGM-506r1.0, EPA Method 8015D	EPA R8		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
	V		EPA Methods 5030B and 8015B	USGS TA		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
Glycols	IV	W	Method in development based on ASTM D773-11	EPA R3		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/R3GlyFinalNSF558_18July2011_1654.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/BenchsheetSamplePreparationLog.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/CalibrationData1.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/CalibrationData2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/CasefileNotes.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/LogbookCopiesRunLogs1.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/LogbookCopiesRunLogs2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/MS_TunesAndStandards1.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/MS_TunesAndStandards2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/MS_TunesAndStandards3.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/MS_TunesAndStandards4.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/MS_TunesAndStandards5.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/OnDemandDataChecklist.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/QualityControlData1.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/QualityControlData2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/QualityControlData3.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/SampleData1.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/SampleData2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/SampleData3.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/SampleData4.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/R3_Phase_IV/SummaryOfResultsProjectInformation1of3.pdf
	V	W	Method in development based on ASTM D773-11	EPA R3		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
	V	W	EPA Method 8015	USGS TA		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
LMWOAs	IV	W	RSKSOP-112v6	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Low_Molecular_Weight_Acids_Phase_IV/ ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Low_Molecular_Weight_Acids_Phase_IV/7OA724SF_SS%236030_HPLC_1of2.pdf

						ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Low_Molecular_Weight_Acids_Phase_IV/7OA724SF_SS%236030_HPLC_queue.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Low_Molecular_Weight_Acids_Phase_IV/7OA724SF_SS%236032_HPLC_2of2.pdf ftp://ftp.epa.gov/r8/pavilliondocs/RawLabData/Phase4/Shaw_Low_Molecular_Weight_Acids_Phase_IV/7OA724SF_SS%236032_HPLC_queue.pdf
	V	W	RSKSOP-112v6	EPA S		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
Ethoxylates, Alkylphenols	V	W	Method in Development based on ASTM D7458-09 and USGS Method O1433-01	EPA LV		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
Acrylamide	V	W	Method in Development based on EPA Methods 8032A and 8316	EPA LV		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
MBAS	V	W	EPA Method 425.1	EPA TA		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/PavillionSeptember2012Appendices.pdf (data summary only)
	V	W	EPA Method 425.1	USGS TA		ftp://ftp.epa.gov/r8/pavilliondocs/phase5/Appendix9_J28076-1_EPA_Std_Tal_L4_Package_MiniFinalReport.pdf
Methanol	V	W	EPA Method SW-846 8015M	EPA S		https://foiaonline.regulations.gov/foia/action/public/view/request?objectId=090004d2806a7021

Abbreviations

C1-C4 – methane, ethane, propane, and butane
VOCs – volatile organic compounds
SVOCs –semi-volatile organic compounds
LMWOAs – low molecular weight organic acids
MBAS –
GRO – gasoline range organic compounds
DRO – diesel range organic compounds
W – water
G – gas
S - solids

Laboratories

A - ALS Laboratory Group, Salt Lake City, UT
A4 - A4 Scientific, The Woodlands, TX
Ada – EPA Office of Research and Development, Ada, OK
C - Chemtech
E - Energy Laboratories Inc., Billings, MT
I - Isotech Laboratories, Champaign, IL
K - KAP Laboratories, Vancouver, WA.
L - Liberty Analytical, Salt Lake City, UT
LV – EPA Office of Research and Development, Las Vegas, NV
R3 - EPA Region 3 Laboratory, Fort Meade, MD
R8 - EPA Region 8 Laboratory, Golden, CO.
S – Shaw Environmental, Ada, OK
TA – Test America, Denver, CO
Z - Zymax

Analytical Methods

ORGM-501r1.1 EPA Region 8 Standard Operating Procedure used with EPA Method 8260 for VOC analysis
ORGM-506 r1.0 – EPA Region 8 Standard Operating Procedure used with EPA Method 8015 for GRO analysis
ORGM-508 r1.0 – EPA Region 8 standard operating procedure used with EPA Method 8015D for DRO analysis
ORGM-515 r1.1 – EPA Region 8 standard operating procedure used with EPA Methods 3520 and 8270D for SVOC analysis
RSKSOP-112v6 – EPA Standard Operating Procedure for Quantitative Analysis of Low Molecular Weight Acids in Aqueous Samples by HPLC
RSKSOP-175v5 - Sample Preparation and Calculations for Dissolved Gas Analysis in Water Samples Using a GC Headspace Equilibration Technique, 16 p.
RSKSOP-194v4 - Gas Analysis by Micro Gas Chromatographs (Agilent MIcro 3000), 13 p.
RSKSOP-213v4 - Standard operating procedure for operation of Perkin Elmer Optima 3300 DV ICP-OES, 21 p.

RSKSOP-214v5 - Quality control procedures for general parameters analysis using Lachat Flow Injection analysis (FIA), 10 p.
RSKSOP-259v1 - Determination of volatile organic compounds (fuel oxygenates, aromatic and chlorinated hydrocarbons) in water using automated headspace gas chromatography/mass spectrometry TEKMAR 7000 HS-Varian 2100T GC/MS system-ION trap detector, 28 p.
RSKSOP-257v2 - Standard operating procedure for elemental analysis by ICP-MS, 16 p.
RSKSOP-299v1 – Determination of Volatile Organic Compounds (Fuel Oxygenates, Aromatic and Chlorinated Hydrocarbons) in Water Using Automated Headspace Gas Chromatography/Mass Spectrometry (Agilent 6890/5973 Quadruple GC/MS System), 25 p.
RSKSOP-276v3 - Determination of major anions in aqueous samples using capillary ion electrophoresis with indirect UV detection and Empower 2 software, 11 p.
RSKSOP-296v0 - Determination of hydrogen and oxygen isotope ratios in water samples using high temperature conversion elemental analyzer (TC/EA), a continuous flow unit, and an isotope ratio mass spectrometer (IRMS), 8 p.
RSKSOP-297v1 – Metals Speciation Determination by LC/ICP-MS, 21 p.
RSKSOP-298v1 - Arsenic Speciation Determination by LC/ICP-MS with Anion Suppression and NaOH Mobile Phase, 21 p.
RSKSOP-313v1 - Determination of R-123 using the H25-IR Infrared Refrigerant Gas Leak Detector, 12 p.
RSKSOP-314v1 - Determination of Fixed Gases using the GEM2000 and GEM2000 Plus Gas Analyzers & Extraction Monitors, 13 p.
RSKSOP-320v1 - Determination of Organic and Inorganic Vapors Using the TVA-1000B Toxic Vapor Analyzer, 18 p.
RSKSOP-330v0 – Determination of Various Fractions of Carbon in Aqueous Samples Using the Shimadzu TOC-VCPH Analyzer, 16 p.
EPA Method 200.7 - Determination of Metals and Trace Elements in Water and Wastes by Inductively Coupled Plasma-Atomic Spectrometry, Rev. 5, Jan 2001.
EPA Method 300.0 - Determination of Inorganic Anions by Ion Chromatography, Rev. 2.1, Aug. 1993.
EPA method 310.1 - Alkalinity (Titrimetric, pH 4.5), Rev. 1978.
EPA Method 350.1 - Determination of Ammonia Nitrogen by Semi-Automated Colorimetry, Rev. 2, Aug. 1993.
U.S. EPA Method 5021A - Volatile Organic Compounds in Various Sample Matrices Using Equilibrium Headspace Analysis, Rev. 1, June 2003.
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U.S. EPA Method 6500 - Dissolved Inorganic Anions in Aqueous Matrices by Capillary Electrophoresis, Rev. 0, Feb. 2007.
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EPA Method 8015B - Determination of Nonhalogenated Organics Using GC/FID, Rev. 2, Dec. 1996.
U.S. EPA Method 8015D - Nonhalogenated Organics Using GC/FID, Rev. 4, May 2003.
U.S. EPA Method 8270D - Determination of Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS), Rev. 4, Feb. 2007.
U.S. EPA Method 8000C - Determinative Chromatographic Separations, Rev. 3, Mar. 2003.
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